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Session: 1. EFFICIENZA

How accurate is yield data across different modern combine harvester brands, crops, growing seasons and geographical area for the application of on farm prescription map?

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Session: 1. EFFICIENZA

Presentation: Oral

Yield data is a cornerstone of agronomic research, essential for evaluating crop rotations, management practices, and genetic improvements. However, traditional manual sampling is often hindered by systematic biases, including lack of standardization, operator-dependent selection of sampling points, and material losses during post-harvest handling. Small-scale manual quadrants (e.g., 1 m²) can capture non-representative conditions, leading to significant over or under estimation of total yield. In contrast, continuous weighing systems on combine harvesters offer automated, georeferenced measurements over larger areas (typically ≥ 6 m²), ensuring higher representativeness and scalability across extensive surfaces. While harvesters provide direct mass measurement unlike the indirect estimates of remote sensing their reliability depends on manufacturer-specific logic (point vs. polygon data) and rigorous calibration. This study aims to: i) quantify the accuracy of modern yield monitors against official weighbridge tickets (DDT); ii) identify the most effective data filtering and rasterization workflows; and iii) apply nutrient removal balances to generate precision fertilization maps. The study was conducted across 40 fields in three Italian regions (Veneto, Marche, and Basilicata) over six cropping seasons (2020–2025). The dataset encompasses five major crops: durum wheat (28 ha), soft wheat (6 ha), maize (75 ha), rice (90 ha), and soybean (80 ha). Accuracy was validated by comparing harvester-generated data with 98 official weighbridge tickets (DDT), serving as the ground truth. The research compared two proprietary data formats: point-based data with rich attributes (John Deere) and polygon-based data (New Holland). To ensure comparability, polygonal data were converted into point-grids (100m²) using the sf

package in R. Each yield record was pre-filtered using various methods and Block Ordinary Kriging was applied. The overall mean error across all crops was 0.58 t ha⁻¹. In durum wheat, John Deere's point-based systems demonstrated significantly higher precision than New Holland's polygonal format, showing a 23% lower mean error and a 45% lower standard deviation. Higher errors were observed in crops with high moisture content at harvest, such as maize and rice. Among the tested workflows, the elimination of yield data when the combine harvester was stationary, traveling at reduced speed, and on fields where there were no physical obstacles and the application of Block Ordinary Kriging reduced both maximum error and standard deviation compared to other methodologies. The choice of data processing significantly impacts nutrient management. Simulated prescription maps based on crop yield harvest balance showed that the best methodology led to a reduction in fertilizer requirements of approximately 7.8% for Nitrogen (N) and 8.2% for Phosphorus (P) and Potassium (K) compared to worst methods. These results highlight that while combine harvester data accuracy is comparable to manual sampling, its scalability and objectivity offer superior operational advantages. To maximize the benefits of precision farming, the study recommends the adoption of high granularity point data and the integration of NIR sensors for moisture measurement. Furthermore, establishing multi-brand data sharing consortiums is essential for validating territorial-scale agronomic models and improving environmental sustainability.

Agronomic efficiency and environmental benefits of traditional surface irrigation: a case study in Northern Italy

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Session: 1. EFFICIENZA

Presentation: Oral

Surface irrigation played an important role in agriculture for centuries in areas rich of water, such as the Po Valley of Northern Italy. In the Piedmont region, surface irrigation is still used by 68% of irrigated farms, mainly for maize and permanent grasslands. Despite its long-standing tradition and low cost, surface irrigation is also well-known for its drawbacks, including high water application volumes, high workloads, night human activity and low irrigation efficiency. In the context of climate change and increasing variability in water availability, improving agricultural water-use efficiency has become both an environmental and societal priority. In this context, the European project MountResilience (Project: 101112876 – HORIZON-MISS-2022-CLIMA-01, 2024–2027) investigates the characteristics and potential of local surface irrigation systems. The project has selected an area in Cuneo Province (Pogliola), as a case study area well representative of local conditions. Pogliola covers approximately 120 ha and includes more than 50 individual fields. Maize and permanent grassland are the main crops. The local Irrigation Consortium coordinates irrigation weekly and Pogliola can access water every Sunday for 25 hours. Water rights are allocated according to field size and expressed in fixed minutes, set historically. During the 2025 growing season, soil characteristics were measured, and interviews with local farmers were conducted to understand management practices. These data, combined with information from the Irrigation Consortium and regional authorities, allowed a preliminary water balance calculation for maize and grassland within the study area. Weather data were obtained from the Regional meteorological station network. Global irrigation inputs (m^3/min) were derived from Consortium information and recording. Internal distribution within the area considered that the planned irrigation schedule assigned to each

field was respected by farmers. The situation was checked through field observation. Calculated outputs included evapotranspiration, surface runoff, and percolation, considering a soil depth of 60 cm. Additional indicators, such as water stress days and soil moisture indices, were also considered. Irrigation efficiency was calculated for every irrigation event. The estimated irrigation efficiencies were, on average, 60% for maize and 63% for permanent grassland, exceeding values commonly reported in the scientific literature. Evapotranspiration losses were higher in meadow and maize followed by a winter crop. At the same time, evapotranspiration decreased in maize followed by bare soil during winter, and in sorghum followed by a winter crop. On the other hand, the lowest evapotranspiration was observed in winter cereal followed by bare soil. Among the non-consumed water fluxes, runoff represented the largest component (from 68% to 47% of the applied water) and, during the irrigation season, remained immediately available downstream of the irrigated area. Percolation losses (from 53% to 32% of the applied water), although reducing water availability at the field scale, contribute to groundwater recharge and support downstream water uses in lower-elevation plain areas. Overall, the study highlights that traditional surface irrigation can provide important environmental benefits beyond field-scale efficiency. Runoff and percolation contribute to downstream water availability and groundwater recharge, supporting regional water balance and agricultural resilience.

Geostatistical evaluation of Sentinel-2 biophysical products and DSS-derived yield estimates for within-field spatial and temporal variability assessment

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Session: 1. EFFICIENZA

Presentation: Oral

Combine harvester yield maps represent one of the most reliable tools for characterizing within-field yield variability and provide a key source of information for precision agriculture applications. However, their availability is still limited in many farming systems, highlighting the need for alternative information sources capable of describing the spatial and temporal patterns of crop production. In this study, georeferenced wheat yield maps were compared with several biophysical products derived from Sentinel-2 satellite imagery and provided by the Copernicus Land Monitoring Service (CLMS). In particular, Leaf Area Index (LAI), Fraction of Vegetation Cover (FCOVER), Fraction of Absorbed Photosynthetically Active Radiation (FAPAR), and Canopy Chlorophyll Content (CCC) were evaluated and compared with yield maps simulated using the Tethys Decision Support System (DSS) and with ground data from a combine harvester yield mapping system. The Tethys DSS integrates satellite observations, the FAO-56 soil water balance approach, and actual evapotranspiration estimates derived from the SEBAL and Penman–Monteith methods. Biomass production is estimated through a radiation-driven model based on FAPAR and crop coefficients (K_c), following a published approach. Crop development and biomass information are subsequently used as inputs to the AquaCrop model for final yield simulation. All spatial datasets were harmonized to a common spatial resolution and compared using combine harvester yield maps as ground reference data. The analysis was conducted through spatially corrected correlation analyses (Dutilleul test), codispersion analysis, Tjostheim's coefficient, Moran's I, variograms, and cross-variograms, in order to evaluate both statistical agreement and similarity of spatial structures. The geostatistical analysis revealed a good spatial agreement between yield maps and several of the investigated indicators, confirming the potential of remotely sensed and model-derived information for characterizing within-field yield variability. The observed relationships suggest that these products can effectively describe spatial patterns of crop production, although differences emerged in their ability to represent specific crop and environmental conditions. The proposed framework enables an integrated evaluation of Sentinel-2 biophysical products and DSS-derived estimates, with the aim of identifying the indicators that are most consistent with observed spatial yield variability. The study also provides useful insights into the contribution of integrating satellite observations and modelling approaches for precision agriculture and site-specific crop management applications.

We are likely overlooking the effects of model users on crop model-based DSS reliability

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Session: 1. EFFICIENZA

Presentation: Oral

Crop models are widely used as engines for Decision Support Systems (DSS) dealing with crop management, resource allocation and climate adaptation. Despite their extensive use, DSS reliability is affected by different sources of uncertainty that may reduce the capability of crop models to provide accurate predictions across different environmental conditions. Although several studies have investigated specific sources of uncertainty in crop model simulations (e.g., quality of inputs, model structure, parameterization), their relative contribution has rarely been evaluated within a unified framework. Here, we simultaneously assessed all possible sources of uncertainty and quantified their relative influence on model outputs, to provide actionable insights for improving the reliability of DSS recommendations. Eight factors known to affect model reliability were considered, each with different levels (in brackets): (i) model structure (WOFOST, STICS), (ii) calibration method (automatic, manual), (iii) use of sensitivity analysis for parameter selection (yes, no), (iv) number of parameters under calibration (few, many), (v) uncertainty in observations (measured, derived with jackknife), (vi) uncertainty in weather inputs (gridded, from weather station), (vii) number of observed state variables (aboveground biomass alone or with leaf area index), and (viii) model users (four trained users). A simulation experiment was carried out involving 64 users arranged in a randomized nested design with four replicates (Fig. 1), where the main plot resulted from different levels of the factors from (i) to (iv) and the sub-plot from the levels of factors from (v) to (vii). For each treatment, the four users (replicates) targeted the best agreement (Relative Root Mean Square Error, RRMSE) between simulated and observed state variables. The simulation experiment was carried out considering rice grown in two different countries (Philippines and Italy), using four datasets for calibration and four for validation. To assess model performance while accounting for both accuracy and robustness, a dedicated error metric (Verifying Illusionary Calibrations, VIC, unitless) was developed to consider both the RRMSE of calibration and validation. Given the necessity to account for the complex experimental design, a linear mixed model (LMM) was used. The LMM included the seven factors from (i) to (vii) and their interactions up to the second order as fixed-effects, whereas the variability due to user subjectivity during the calibration was considered as a random effect. Partial eta squared was used to quantify the proportion of the total variance of VIC explained by each factor. Results highlighted that the largest proportion of the total variance of VIC was explained by the user effect (20% in Italy and 29% in the Philippines). Among fixed effects, the most relevant were related with the model structure (ranked 2nd in both countries), calibration method (ranked 1st in the Philippines and 3rd in Italy), the quality of observations (3rd and 4th in

the Philippines and Italy), and the quality of weather inputs (ranked 1st in Italy). Our results clearly underlies that the level of the skills of the model user may have a larger impact compared to all other sources of uncertainty.

Spaceborne Hyperspectral Data for Farm-Level Decision Support Systems in Paddy Rice

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Abstract ID: 167

Session: 1. EFFICIENZA

Presentation: Pitch

Over the past 30 years, Earth Observation (EO) has been widely used to support agroecosystem monitoring initiatives at the regional scale. In Europe, for example, EO data is integrated into platforms such as the JRC MARS Bulletin and the AGRI4CAST Toolbox, which are designed to provide near-real-time data on crop conditions and weather impacts for risk financing mechanisms and Common Agricultural Policy (CAP) interventions. At the farm level, however, despite the latest advances in EO data in terms of spatial resolution and frequency, there is still a gap between the data provided and what the farmer actually needs, especially in smallholder farming systems. Decision Support Systems (DSS) that aim to optimize the use of external inputs require accurate, timely, and spatially explicit information on leaf-level biochemical variables, such as nitrogen and chlorophyll content. Until now, the production of this information from space has remained challenging. With the launch of experimental hyperspectral high-resolution satellite missions (e.g., PRISMA, EnMAP, CHIME), and recent advances in Machine Learning (ML) and AI-driven approaches, we may be closer than ever to fill this gap, in particular for direct nitrogen estimates. To test this, we develop a retrieval framework for estimating structural and biochemical traits of paddy rice under commercial farming conditions in northern Italy. The approach integrates field spectroscopy and agronomic measurements collected during the 2023 growing season ($n = 120$) with ML models trained on spectra resampled to satellite spectral responses. Model transferability was evaluated on independent 2024 datasets by synergically exploit multi-temporal hyperspectral acquisitions from PRISMA and EnMAP missions ($n = 20$). Results demonstrate high accuracy for structural variables, including Leaf Area Index (LAI; $R^2 = 0.81$, RMSE = 0.30) and dry Aboveground Biomass (dAGB; $R^2 =$

0.81, RMSE = 183.2 g/m²). Leaf-level biochemical traits showed moderate but meaningful performance, with Leaf Chlorophyll Content (LCC; R² = 0.59) and Leaf Nitrogen Concentration (N%; R² = 0.39) successfully capturing spatial and temporal variability consistent with crop physiology and management. The synergistic use of PRISMA and EnMAP improves the temporal frequency of spaceborne hyperspectral data to enable seasonal monitoring of crop dynamics in canopy development and nitrogen status. As a proof-of-concept for DSS, satellite-derived N% and dAGB were combined to produce spatially explicit Nitrogen Nutrition Index (NNI) maps, revealing intra-field variability and temporal transitions from nitrogen deficiency to optimal conditions and subsequent depletion during grain filling. The derived NNI showed a significant relationship with final grain biomass, highlighting its agronomic relevance for yield-oriented management and potentially as an indicator of field level productivity. These findings demonstrate that spaceborne hyperspectral spectroscopy, when coupled with state-of-art ML models, enables consistent estimation of both structural and biochemical crop traits, including indicators directly linked to nutrient status fundamental for smart management application. This approach represents a key step toward bridging the gap between EO data and farm-level DSS, providing a scalable pathway for operational monitoring of crop nitrogen status and supporting more efficient and sustainable agricultural practices.

Spatial variability of nitrogen losses and uptake

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Session: 1. EFFICIENZA

Presentation: Pitch

The major challenge addressed is the systemic mismanagement of nitrogen (N) fertilizer in agricultural fields leading to problems such as leaching of nitrates into groundwater and emission of harmful greenhouse gases. Digital technologies are commercialized in agriculture (available from the early 1990s) have failed with N fertilization. Despite agriculture is the least digitized sector (as highlighted at the last World Economic Forum) to make a reliable recommendation, researchers need to extract and simplify complex science into practical and relevant information enabling advisors and farmers to use such information to make N recommendations for individual fields. But severe bottlenecks in research, development and application of precision agriculture cause key research to be disconnected. The objective of the presentation is to show experimental results of nitrogen losses from leaching and emission. Two experimental fields and one farmer field are shown, both located in central Denmark. The first field (D1) is a 6 ha field where a uniform fertilization strategy was applied to spring barley during the growing seasons 2024 and 2025, with 48 sampling points for different plant and soil properties. For the 2026 growing season a strip trial experiment on spring wheat compared uniform vs. site-specific fertilization (prescription map provided by a commercial company), and where the same measurements made in 2024 and 2025 were done. Nitrate leaching was measured with installed suctions cups in the 48 points while greenhouse gas emissions (N₂O) were measured with AERIS Mira. Soil mineral nitrogen was measured 7 times during growing season and soil water with TOMST probes (15-min interval). In addition a 2.5 ha experiment field (SR) setup for the 2026 growing season with 3 treatments (no fertilization, normal fertilization, and liquid biofertilizer) replicated 4 times on 18x18m plots with both annual and perennial cereals. Same measurements were made also in this experimental plots. Finally a 50 ha farmers' field (FF) was also mapped and measured for the 2025 (leaching and emissions) and 2026 (only leaching). For both growing season the farmer adjusted in replicated strips different plant densities. UAV multispectral and thermal imaging to monitor in-season crop health status and spatial variability for all fields. Results show a large spatial and temporal variability of nitrogen losses with zones in the field (D1) prone to more leaching losses while others more prone to N₂O emissions. While in the farmer's field most of the variability was due to soil structure. At the end of the 2026 growing season we will evaluate the ability of precision management (fertilization in D1 and plant density in farmer's field) to optimize the tradeoff between productivity and sustainability.

Effects of forest thinning on forage production and pastoral value in a mediterranean silvopastoral system

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Session: 1. EFFICIENZA

Presentation: Pitch

Mediterranean silvopastoral systems represent multifunctional landscapes where forestry, grassland, and livestock management coexist to provide essential ecosystem services, primarily sustainable forage provision. This study investigates how forest management practices, consisting in different thinning treatments, may influence forage yield and pastoral value within a Mediterranean silvopastoral system located at the Tenuta di Paganico farm in Tuscany, Italy. The research aims to better understand how different thinning intensities influence the balance between herbaceous and shrubby layers, in order to support sustainable grazing management for the Maremmana cattle breed. The experimental design was established in an area previously treated in the 1980s and subjected to new thinning operations between 2018 and 2020. Sixteen permanent plots (2x2 m) were monitored across four distinct treatments: 8-10 m width forest strips (B); 6 m width clear-cut strips (L); 4 m width clear-cut strips (S); unthinned forest strips (control) (F). Over a two-year period, according to the simplified method, the seasonal field campaigns measured dry matter production, floristic composition, and forage quality and Pastoral Value (PV) of the grasses and shrub layer under the tree canopy cover of the 4 treatments. Statistical analyses, including ANOVA and Tukey's tests, were applied to assess the impact of these treatments on pastoral value (PV) and biomass over the different seasons of the year. The results demonstrate that forest management significantly shapes the understory structure. Herbaceous biomass production was markedly enhanced in the 6 m clear-cut strips, reaching peaks of 451.2 ± 43.8 kg ha⁻¹. In contrast, unthinned strips produced significantly less, averaging 250 ± 85.0 kg ha⁻¹. This increase in yield was coupled with a higher PV in thinned areas (PV = 28.6 ± 1.2) compared to unthinned strips (PV = 14.5 ± 2.0). This trend likely reflects the

positive response of herbaceous species to increased light availability and reduced belowground and aboveground competition following thinning. While canopy openings favoured herbaceous production, unthinned areas maintained a more persistent shrub layer, potentially contributing to ecological resilience, summer forage availability and microclimatic buffering. However, the study notes that excessive thinning may lead to functional simplification by favouring pioneer species at the expense of long-term botanical quality. Seasonal variability was also pronounced, with production peaks in spring and autumn and significant declines during the summer due to Mediterranean climatic constraints (e.g. droughts). The study concludes that thinning intensity is a primary driver of the balance between shrub and herbaceous layers. Intermediate thinning and carefully designed clear-cut strips appear to provide the best trade-off for silvopastoral purposes. Creating a management mosaic of differently treated patches is recommended to ensure ecological resilience, maintain biodiversity, and provide a more stable and higher-quality forage supply for extensive livestock systems.

Gluten Immunogenicity as an Emergent Agronomic Trait: Evidence from Cultivar × Environment × Management Studies in Durum Wheat

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Session: 1. EFFICIENZA

Presentation: Pitch

The accumulation of immunogenic (IP) and toxic (TP) gluten peptides in durum wheat grain is attracting increasing attention because of its implications for grain quality and human nutrition. Although differences among cultivars are known to influence the occurrence of celiac disease-related epitopes, the contribution of environmental conditions and crop management remains less clearly understood. This contribution integrates evidence from three complementary studies aimed at identifying the agronomic drivers of peptide accumulation in durum wheat. Multi-environment field trials conducted across contrasting Italian growing areas showed that environmental conditions strongly influence peptide accumulation and that agro-meteorological variables associated with water availability, evapotranspiration and crop development are significantly related to the abundance of IP. Notably, grain yield and grain protein concentration were poor predictors of peptide accumulation, indicating that conventional quality indicators do not adequately describe this trait. A complementary molecular characterization approach confirmed the existence of a varietal component and identified several trait determinants associated with differences in gluten composition and peptide accumulation. However, the observed variability could not be explained by single major factors, suggesting a complex regulation involving multiple biological processes. Finally, multifactorial agronomic trials demonstrated that nitrogen fertilization, sowing density and sowing date can significantly affect peptide accumulation, although management responses were strongly cultivar-dependent. Specific cultivar-management combinations were identified that reduced peptide levels while maintaining satisfactory productivity and technological quality. Overall, the results consistently indicate that the final concentration of IP and TP in durum wheat grain is the outcome of the interaction between cultivar, environment and management. From this perspective, gluten immunogenicity can be interpreted as an emergent agronomic trait rather than a purely varietal characteristic. The findings highlight the opportunity to complement varietal improvement with targeted agronomic strategies aimed at mitigating peptide accumulation through the

optimization of cropping practices and adaptation to local environmental conditions. This integrated framework may support the development of durum wheat production systems capable of combining productivity, technological quality and reduced gluten immunogenicity.

Drought-tolerant maize for climate change adaptation: agronomic and economic perspectives

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Session: 1. EFFICIENZA

Presentation: Pitch

The effects of climate change on maize production are expected to intensify in the coming decades leading to new challenges for the production of this key crop for the agri-livestock sector. Higher temperatures and an increased frequency of drought events are projected, particularly in hotspot areas such as the Po Plain, where approximately 90% of the national maize production is concentrated (about 500,000 ha). In this context, the development and adoption of maize hybrids selected to be more resistant to drought conditions are essential to maintain crop productivity. In this study, we evaluated the performance of drought-tolerant maize hybrids over a three-year period (2023–2025). Performances of selected drought-tolerant hybrids were compared with their respective conventional hybrids under different environmental and management conditions. Two maturity classes (FAO 300 and FAO 500) were considered, with one conventional and one drought-tolerant hybrid evaluated within each class. Field experiments were conducted both under experimental and on-farm conditions. At the experimental center of the University of Turin trials were conducted to evaluate two irrigation regimes: fully irrigated and rainfed. In the fully irrigated treatment, irrigation volumes corresponded to 100% of crop evapotranspiration (ET_c) net of precipitation, and water was applied using a sprinkler irrigation system. On-farm trials were carried out in four commercial farms located in different areas of Piedmont region, where crops were managed either under full irrigation or rainfed conditions, representing the main maize management of each area. Measured parameters included grain yield, quality traits, mycotoxin contamination and efficiency indicators (i.e. nitrogen use efficiency and water productivity). An economic analysis was also performed to compare the profitability of conventional and drought-tolerant hybrids adoption. Results showed that drought-tolerant hybrids achieved higher grain yield in 77% of the cases at the experimental site and in 68% of the cases across commercial farms. However, no statistically significant differences were detected between conventional and drought-tolerant hybrids. Likewise, irrigation treatment did not significantly affect grain yield at the experimental center of the University of Turin. On the other hand, significant differences were observed between FAO maturity classes (P-value < 0.05), with FAO 500 hybrids consistently outperforming FAO 300 hybrids in terms of yield. No significant differences in starch content were observed between the hybrids. Similarly, no significant differences were detected between drought-tolerant and conventional hybrids in the

concentrations of aflatoxin, fumonisin, and zearalenone. The average nitrogen use efficiency (NUE) was 0.54 and did not differ significantly between the two hybrid groups. Although drought-tolerant hybrids exhibited higher water productivity than conventional hybrids, the difference was not statistically significant. From an economic perspective, the drought-tolerant hybrids showed higher economic efficiency than their conventional respective in 11 out of 14 comparisons within the same maturity class. Overall, the adoption of drought-tolerant hybrids could represent a promising strategy for climate change adaptation, contributing to greater resilience and sustainability of maize production systems. Furthermore, the positive economic performance observed for drought-tolerant hybrids may encourage farmers to adopt these materials as a means to improve farm profitability under increasingly variable climatic conditions.

Assessing the Efficiency of Mediterranean Agroforestry Systems

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Session: 1. EFFICIENZA

Presentation: Pitch

Traditional Mediterranean agricultural landscapes have historically relied on diversified, low-input systems. Modern agricultural intensification has led to widespread monoculture, accelerating soil degradation and climate vulnerability. This study evaluates the ecological and agronomic performance of an agroforestry system that intercroops olive trees (*Olea europaea* L.) with winter cereals. Three cereal varieties were tested: a durum wheat landrace (*Triticum durum* Desf., cv. Timilia), an evolutionary common wheat population (*Triticum aestivum* L., cv. Solibam), and a rye variety (*Secale cereale* L., cv. Irmanu). To assess broader crop diversity, a fava bean variety (*Vicia faba*, cv. Sikania) was introduced into the system during the second year. All herbaceous species were also cultivated in open-field monocultures outside the olive grove to serve as a production baseline (control). The trial was conducted in the province of Catania (Sicily), at an elevation of 960 m above sea level. The climate of the area is Mediterranean with relatively high annual precipitation (approximately 1200 mm year⁻¹). Over a two-year experimental period (2023 and 2024), climatic dynamics, crop yields, quality parameters, light competition, and Land Equivalent Ratio (LER) were assessed. To quantify the light dynamics within the alley-cropping system, photosynthetically active radiation (PAR), was systematically monitored across multiple phenological stages of the herbaceous crops throughout the growing season. Canopy light interception was measured using an AccuPAR LP-80 linear ceptometer (Meter Group Inc., USA). To capture the spatial heterogeneity created by the olive tree canopy, PAR measurements were recorded at varying positions and horizontal distances from the trees. At each sampling point, measurements were taken at two distinct vertical heights: directly above the crop canopy (to capture radiation filtered by the trees) and at the soil surface (to measure radiation penetrating the crop). Simultaneously, incident PAR was recorded in the adjacent open-field monoculture plots to serve as the total reference radiation. The results indicate that while the tree canopy reduced incident photosynthetically active radiation (PAR) by 25 - 40% in areas immediately adjacent to the tree rows, it significantly mitigated extreme summer soil temperatures and reduced evapotranspiration losses. Light availability for the cereal crop was highest in the center of the alleys, whereas areas closer to the tree rows experienced significant shading, with the lowest light levels recorded directly beneath the tree canopy projection. A positive correlation between the amount of PAR intercepted by the crop and the biomass and grain yield was observed and the highest values of biomass yield for each species were achieved in the position with the highest values of PAR interception. The yield decline close to the tree lines was offset by a total LER ranging from 1.2 and

1.6, in both growth seasons, demonstrating a clear overyielding advantage compared to standalone monocultures.

Soil fatigue associated to grain legume cultivation impairs pea (*Pisum sativum* L.) Seedling establishment

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Presentation: Poster

The simplification of cropping systems and the increasing frequency of grain legume cultivation in the same fields may compromise soil biological functionality and reduce crop performance over time. Although grain legumes are widely recognized for their contribution to biological nitrogen fixation and agroecosystem sustainability, intensive grain legume cultivation can promote the accumulation of soil-borne pathogens and generate conditions commonly referred to as “soil fatigue”. These processes may negatively affect seed germination, root development, and crop establishment, ultimately threatening the long-term sustainability of legume-based systems. The present study aimed to investigate the effects of soil fatigue associated with continuous grain legume cultivation on pea (*Pisum sativum* L.) germination and early growth. A pot experiment was conducted under controlled environmental conditions using soils collected from 21 farms characterized by a history of repeated pea cultivation. Two soil management conditions were compared: non-sterilized soils (Control, C), representing the original biological condition of the field soils, and sterilized soils (S), thermally treated at 160°C for 2 hours to reduce soil microbial and pathogen pressure. Pea seeds were sown in pots containing the different soil samples and monitored for six weeks. Germination dynamics and germination rate indices were periodically assessed during the emergence phase, while plant height measurements were recorded throughout crop establishment. At the end of the experiment, aboveground biomass production and root health status were evaluated in order to characterize the effects of soil conditions on plant development. The results demonstrated a strong effect of soil origin on pea establishment and early growth, confirming the presence of soil fatigue phenomena in several of the investigated soils. Non-sterilized soils frequently delayed seed germination and, in some cases, significantly reduced seedling emergence, indicating unfavorable biological conditions likely associated with pathogen accumulation under continuous monocropping. In contrast, soil sterilization consistently improved germination dynamics, promoting faster and more uniform emergence and increasing germination rate indices across most soil samples. Plant growth responses reflected the same trend observed during germination. Pea plants cultivated in sterilized soils generally showed greater height and more vigorous aboveground development

compared with plants grown in untreated soils. Moreover, aboveground biomass accumulation was significantly enhanced following soil sterilization, suggesting that soil-borne biotic stress represented a major limiting factor during the early developmental stages. Root assessments further supported these findings, as plants grown in non-sterilized soils frequently exhibited visible symptoms of root damage and poor root system development. Overall, the study highlights the importance of soil biological fertility in maintaining productive and resilient grain legume systems. The results demonstrate that continuous grain legume monocropping can induce soil fatigue processes capable of impairing crop establishment and early growth. These findings emphasize the need for diversified crop rotations and sustainable soil management strategies to preserve soil health and reduce the risks associated with pathogen build-up in intensive legume-based systems. In the context of the agroecological transition, improving crop diversification and restoring soil functionality represent key priorities for enhancing the sustainability and resilience of Mediterranean arable farming systems.

A Decision Support System for Nitrogen Management in Wheat under Variable-Rate Fertilization

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Presentation: Poster

Wheat nitrogen (N) fertilization management requires careful optimization to primarily enhance productivity and protein content while minimizing the risk of over-fertilization and improving N Use Efficiency (NUE), particularly under field conditions characterized by high spatial variability, where variable-rate application can be advantageous. In wheat, N fertilization is commonly performed at tillering (GS23) and at the beginning of stem elongation (GS31) to enhance the number of fertile stems and spikelets, respectively, whereas an additional application at heading (GS55) may be used to improve grain protein content. Most Decision Support Systems (DSS) guide wheat N fertilization using vegetation indices such as the Normalized Difference Vegetation Index (NDVI) which is closely related to crop biomass and nutritional status. In this context, this study aims to develop a simple DSS to support the N fertilization at tillering and stem elongation of winter wheat genotypes, using the NDVI acquired immediately prior to fertilizer application. A field plot experiment was conducted over a three-year period (2023-2025) in Piedmont (Italy). The study compared a factorial application of four N rates at tillering (0, 33, 66, 99 kg N ha⁻¹) with five N rate at stem elongation (0, 33, 66, 99, 132 kg N ha⁻¹). Treatments were applied to a high-yielding conventional wheat commonly grown in the area (LG Ayrton) and to a high-vigor and NUE pre-commercial hybrid wheat (SY8223146). Before N fertilization (GS23 and GS31), NDVI was acquired by an active proximal sensor (Rapidscan®). Grain yield and NDVI data were used to calibrate response curves relating N requirements to NDVI indicators at different growth stages. In particular, the calibrated models were used to estimate N applications at GS23 and GS31, based on target NDVI at GS31 and target yield, respectively, following a two-step approach. The NDVI-based models (Figure 1) reliably predicted the N rate required at tillering and at stem elongation for both genotypes. Compared to the conventional genotype, the hybrid required approximately 35 kg N ha⁻¹ less at GS23 to achieve the target NDVI at stem elongation, despite a lower baseline NDVI values due to its lower seeding density. Moreover, the models indicated a further reduction of 30 kg N ha⁻¹ at GS31 for the hybrid genotype compared to

the conventional wheat, starting from the same stem elongation NDVI values to achieve the maximum yield. Both models showed high accuracy. For tillering fertilization, the average underestimation was 10 kg N ha⁻¹ when comparing the predicted N rate with the actual N rate required to achieve the observed NDVI at GS31. For stem elongation fertilization, the average underestimation was 18 kg N ha⁻¹ when comparing the predicted N rate with the actual N rate required to achieve the measured yield. These results highlight the effectiveness of the proposed NDVI-based DSS in supporting a two-step N fertilization strategy aimed at maximizing yield. Nevertheless, additional research is needed to validate and refine the approach for predicting N requirements related to grain quality, particularly protein content and to further support in-field evaluation of the criterion for variable-rate management.

Short stature corn performance under different N fertilization strategies

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Presentation: Poster

Short stature corn (SSC) hybrids, characterized by reduced internodes length compared to the tall stature corn (TSC), represents the major genetic innovation in modern corn cultivation. The incorporation of a variant of the *brachytic2* gene reduces plant and ear insertion height, improving standability and potentially allowing to increase plant density, leaf area index and optimize solar radiation interception. In TSC, in-season nitrogen (N) fertilization is commonly performed at the 7 leaves stage (GS17), the latest stage at which field operations can be performed without risking crop damage caused by tractor traffic. However, the reduced internode length may allow to postpone the in-season N fertilization at the beginning of stem elongation (GS31), closer to the maximum crop nutrient uptake. In this context, this study evaluated the effects of different fertilization strategies in SSC compared with the conventional TSC management across three soil types. A three-year experiment was carried out at the experimental farm of the University of Turin in 3 fields with different soil textures (Loamy, Silty-Loamy and Silty-Clay-Loamy). The study compared a TSC hybrid (DKC6808) fertilized at the GS17 (TSC_N17), SSC (DKC7236SC) fertilized at GS17 (SSC_N17), SSC fertilized at the beginning of stem elongation (SSC_N31) and SSC receiving split fertilization at 5 leaves stage (GS15) and the beginning of stem elongation (SSC_N15+31). All treatments received in total 250 kg N ha⁻¹ as urea. Plant density was 8 and 12 plants m⁻² for TSC and SSC, respectively, with 0.75 m inter-row distance. Grain yield and yield components were measured. Moreover, nutritional status was assessed through the NDRE index from a multispectral drone-mounted camera and through ear-leaf chlorophyll content. Treatment differences were analyzed by a two-way ANOVA with year and treatment as fixed factors within each soil type. Figure 1 shows the effects of the different treatments on yield across years and soil types. Under the same N fertilization strategy (N17), SSC outperformed TSC by 15% on average across soils and years. Overall, the split N fertilization strategy (N15+31) produced the highest yields (+7.5% than SSC_N17 treatment), whereas the SSC_N31 treatment generally resulted in the lowest yields (-10% than N17 treatment and comparable to the TSC). The advantage of split N fertilization was more evident under high spring rainfall conditions (2023 and 2024) and in Loamy soil, whereas no significant yield differences

between N15+31 and N17 were observed in Silty-Loamy and Silty-Clay-Loamy soils, likely due to higher cation exchange capacity. Yield gains in SSC were mainly associated with a higher number of kernels per square meter (+22%), driven by an increased ear density (+40%) despite fewer kernels per ear (-15%). Crop nutritional status also confirmed the benefits of split fertilization marked in Loamy soil, with statistically higher chlorophyll content (+4%) and NDRE (+8%) values at the waxy stage compared to SSC_N17 treatment. Overall, SSC hybrids combined with split N fertilization may improve yield stability and N management efficiency, particularly in soils with lower cation exchange capacity, while the reduced plant height facilitates split late in-season N applications compared with conventional TSC hybrids.

Durum wheat (*Triticum durum*) hyperspectral response to nitrogen fertilization across phenological stages under Mediterranean conditions.

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Session: 1. EFFICIENZA

Presentation: Poster

Together with maize and rice, wheat provides more than 50% of the world's caloric intake, demonstrating its importance for food security. To meet the growing global demand for food, wheat production will need to increase by more than 40% in the coming decades. Nitrogen (N) is a key nutrient for durum wheat as it significantly affects both vegetative growth and grain yield and quality. Since N fertilization represents one of the main costs for wheat farmers, its management is critical to improving N use efficiency and reducing negative environmental impacts and production costs. Traditional methods for estimating plant N status are destructive, time-consuming and poorly representative of spatial and temporal field variability. Therefore, hyperspectral sensors provide a potential alternative to detect N stress, enabling targeted and timely agronomic actions. This study aims to assess the effects of different N fertilisation levels and the application of a soil endomycorrhizal inoculant on traditional biometric and eco-physiological variables in durum wheat. The objective is also to characterize wheat response to N fertilization levels through hyperspectral reflectance analysis, by detecting changes in canopy spectral signatures and exploring the relationships between measured variables and raw spectra. A field experiment was conducted during 2026 growing season at the Council for Agricultural Research and Economic Analysis (CREA) farm in Rutigliano (Bari, Southern Italy). A split-plot experimental design was established with N fertilization (0, 50, 100, and 150 kg ha⁻¹ N) as main plot factor and the application of the endomycorrhizal inoculant as subplot factor. Dry aboveground biomass (AGB), leaf area index (LAI), chlorophyll content index (CCI), relative water content (RWC) and stomatal conductance (gs) were collected at tillering, stem elongation, booting, milk ripening and dough ripening phenological stages,

simultaneously with the acquisition of canopy spectral signatures using the ASD FieldSpec 4 Spectroradiometer (350–2500 nm). Yield response variables were also measured at harvest. N fertilization levels significantly affected AGB and CCI at all phenological stages, whereas LAI was significantly affected only from the booting stage onwards. Furthermore, the interaction effect between the two factors was statistically significant for CCI at milk and dough ripening. Across the raw spectrum, Pearson correlation coefficients between reflectance and AGB, LAI, and CCI exhibited negative values in the visible (Vis) region, shifting to positive values in the near infrared (NIR) via the red-edge transition region and returning negative in the shortwave infrared (SWIR) with peak absolute correlation coefficients of 0.75 reached at booting and milk ripening stages. Significant correlations were observed for *gs* and RWC only in restricted spectral ranges across phenological stages and with correlation coefficients remaining consistently low. When performed separately on Vis, NIR and SWIR spectral range, principal component analysis (PCA) showed that the first two PCs account for over 95% of the total variance in all three analyses. Observations segregated according to N treatments and across phenological stages, mainly along PC2 axis. The 720–760, 1180–1230 and 1300–1340 nm ranges exhibited the greatest weight on discriminating durum wheat status in response to N availability.

In silico phenotyping of barley genotypes through the integration of biophysical modelling and genomic prediction

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Session: 1. EFFICIENZA

Presentation: Poster

Genomic Prediction (GP) has been developed for deriving in silico the values of phenotypic traits from genomic information. This allows expanding the size of breeding programs without increasing the resources for field trials. Conventional GP derives statistical relationships between genomic information (SNPs) and phenotypic data for a training set of genotypes and uses these relationships to predict the phenotype of new accessions as a function of their marker profiles. However, plant phenotypic plasticity makes statistics unsuitable to properly account for $G \times E \times M$ interactions, given the variety of environmental and management factors that could alter the relationships between SNPs and trait expression. As a consequence, such statistical relationships can be considered valid only under the conditions for which they were derived. To overcome these limitations, recent studies are integrating GP and crop models (CSMs). The rationale is using GP to predict, starting from SNPs, traits that are only lightly affected by $G \times E \times M$ (e.g., leaf thickness) and using CGMs to explicitly reproduce $G \times E \times M$ on an eco-physiological basis. This implies that CSM-aided GP (CSM-GP) can be used outside the conditions explored for the collection of phenotypic data, thus including new geographical regions and new management and climate scenarios. Despite the theoretical advantages, CSM-GP can be affected by different sources of uncertainty, like the modelling approach and the number of parameters (representing functional traits) considered. These sources of uncertainty can expose to high risk of equifinality, which can undermine the biological meaningfulness of the prediction. This study aimed at quantifying the impacts of these sources of uncertainty on the accuracy and biological meaningfulness of a 2-step CSM-GP for predicting the heading date (HD) of 151 2-row spring barley genotypes using a 50K SNPs array and HD collected in 17 environments from Northern Africa to Northern Europe. To account for the first source, two CSMs (WOFOST and SiriusQuality) largely differing in complexity were selected, whereas for the second, four configurations with increasing number of parameters were generated for each CSM by progressively adding parameters starting from the two most relevant, ranked according to their SA total-order effect. For both models, the biological meaningfulness significantly decreased while increasing the number of parameters (Fig.1) because of the increased prevalence of equifinality. However, HD predictions for all model configurations were satisfactory ($r \geq 0.98$) when analysed considering all genotypes in all environments thanks to the large variability in the environmental conditions explored, whereas a clear worsening in prediction accuracy from training to test was

highlighted within environment, even due to the small differences between genotypes. Moreover, SiriusQuality showed a sharp decrease in accuracy when more than four parameters were used, probably due to the extent of the interactions between parameters (difference between total- and first-order SA effects) that amplified the risk of equifinality. For these reasons, we strongly suggest to run CSM-GP using the minimum number of parameters and to use a CSM with few interactions between parameters, information that can be derived by using SA results in terms of both parameter relevance and interactions.

Supporting water stress management in vineyards through smartphone-based estimates of stomatal conductance

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Presentation: Poster

Effective water stress management in vineyards is becoming increasingly challenging because of the raising frequency and intensity of drought events associated with climate change. Although grapevine is generally considered a drought-tolerant species, excessive water deficit can severely compromise yield, while mild-to-moderate water stress conditions are often desired by farmers because of their positive effects on grape quality. In this context, reliable and rapid tools able to accurately and timely assess vine water status are increasingly needed both for optimizing irrigation practices and for supporting alternative drought-mitigation strategies in rainfed vineyards. Over the past decades, several approaches have been proposed, ranging from remote sensing techniques to various in-field sensors. However, limitations related to costs, reliability, or applicability still restrict their use as stand-alone solutions under operational farming conditions. This work aims at presenting a new mobile technology (PocketSTRESS) – recently developed – which provides farmers with easy-to-interpret information on vineyard water status. The app implements a published approach, based on the estimation of stomatal conductance (g_s) – considered a reliable indicator of water status – from changes in leaf orientation triggered by physiological mechanisms (e.g., decrease in leaf turgor) involved in vine response to water stress. Specifically, PocketSTRESS uses the sensors available in common smartphones to acquire 3D leaf scans directly in the field. During the scan, the system collects leaf inclination angles and automatically derives the χ parameter of Campbell's ellipsoidal leaf angle distribution, used as a synthetic index characterizing the degree of leaf tissue erectness. Cultivar-specific relationships are then used to estimate g_s as a linear function of χ . Estimated g_s values are automatically compared with known g_s thresholds corresponding to different water stress levels for classifying vine water status in four categories: no stress, mild, moderate, and severe stress. Dedicated trials – with different irrigation treatments applied – were carried out from 2021 and 2024 to derive g_s - χ relationships for cvs. Chardonnay, Malvasia, Pinot Blanc, Sangiovese, and Montepulciano. In addition, to provide transparent and quantitative

information on the performances and limitations of the method, the accuracy of PocketSTRESS (trueness and precision) was evaluated according to the ISO 5725 protocol adapted for in vivo methods. The obtained relationships allowed to explain, on average, about 80% of g_s variability, confirming the robustness of the proposed approach across cultivars and environmental conditions. The app effectively discriminated stressed from non-stressed vines, with only two out of 49 mildly stressed plants incorrectly classified as non-stressed. Overall, 71% of cases were correctly assigned to the expected water stress category, while misclassifications never exceeded one stress class. Results also highlighted satisfactory performances in terms of accuracy, with limited effects of operators and environmental conditions on method precision. Compared with traditional approaches for g_s determination, PocketSTRESS provides operational advantages in terms of rapidity, usability, and cost-effectiveness. Its extendibility to additional cultivars, together with the interpretability of the outputs, makes PocketSTRESS a promising tool to support water stress management in viticulture, also for medium and small farms.

Topping Industrial Hemp (*Cannabis sativa* L.) to Facilitate Mechanical seed Harvest in Short Supply Chain Systems

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Presentation: Poster

Italian production of industrial hemp seed for human and animal consumption is predominantly managed within short supply chain systems. The limited cultivated areas preclude the economic investments required to purchase dedicated harvesting machinery. The characteristically tall stature and high intra-canopy height variability of industrial hemp pose significant challenges to mechanical seed harvesting using conventional farm equipment, including modified combine harvesters employed for other crops. The present study investigates the potential of topping (apical shoot removal) as a cultural practice to facilitate hemp seed harvesting with non-specialized machinery. Topping is known in other contexts (sugar beet for seed production), but its systematic application to seed hemp for mechanical harvesting purposes is little explored in the literature. This practice aims to reduce overall plant height and improve canopy height uniformity. Such morphological modifications are expected to enhance the operational performance of standard harvesting equipment by reducing the volume of fibrous biomass that machines must process in their threshing and separation systems. A field trial was conducted in 2023 at the experimental farm of CREA-CI (Rovigo, Italy), comparing topped versus non-topped plants of two monoecious hemp varieties bred for seed production: Codimono - a CREA-CI variety - and Futura 75 - a commercial reference variety widely adopted in the Italian market. Parameters assessed at harvest included canopy height uniformity, and seed yield. Topping, performed approximately 50 days after sowing, significantly reduced and uniformized plant height at harvest. Furthermore, secondary stems developing after apical removal exhibited markedly smaller diameters, thereby reducing mechanical impedance during biomass transit through the harvester. Seed yield responses to topping, however, differed between the two varieties, highlighting a genotype X management interaction that leads to further investigations across multiple growing seasons. These results open up to other interesting investigations, for example which varietal characteristics predict a positive response and highlight how this technique could encourage sustainable crop diversification by reducing burdens for small farmers who want to include hemp in their crop rotation.

Physiological Drivers of Yield Stability in Cotton Under Deficit Irrigation

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Presentation: Poster

The selection of drought-resistant cotton genotypes with high productivity and improved water-use efficiency is an increasingly pressing challenge in arid and semi-arid cotton-growing regions, where climate variability is intensifying water scarcity. This study evaluated two widely cultivated cotton varieties in Texas, NG 4190 B3XF and ST 4990 B3XF, under full and moderate deficit irrigation to identify physiological markers associated with contrasting yield responses under water limitation. A comprehensive set of physiological traits was assessed, including plant water status, leaf gas exchange, carbon isotope composition ($\delta^{13}\text{C}$), total nitrogen and C/N ratio, chlorophyll fluorescence, light and CO_2 response curves, and canopy temperature. While no yield differences were observed under full irrigation, moderate water deficit resulted in stable seed and fiber yield in NG 4190, but significant yield reduction in ST 4990. Yield differences were not explained by instantaneous gas exchange or direct biochemical limitations of photosynthesis, but rather by integrated physiological behavior over time. Key discriminating traits included midday relative water content (RWC), photosynthetic light-response parameters (α and P_m), stomatal optimization parameter (g_1), and $\delta^{13}\text{C}$. NG 4190 exhibited higher RWC, more negative $\delta^{13}\text{C}$, and higher g_1 values, indicating a less conservative stomatal regulation strategy that supported sustained carbon assimilation under water stress. These findings provide insight into the physiological mechanisms underlying cotton performance under drought and support the use of integrated physiological markers for the selection of resilient genotypes in water-limited environments.

Spatial and temporal evaluation of pastoral value in the Eastern Alps using remote sensing

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Session: 1. EFFICIENZA

Presentation: Poster

Semi-natural mountain pastures provide essential ecosystem services, including forage production and biodiversity conservation. In many parts of the European Alps, the long-term declines in animal utilization have led to widespread undergrazing and progressive pasture degradation, with shrub encroachment into open areas and an overall decline in forage quality and plant diversity. In this context, reliable information on pasture quality and productivity becomes critical to effectively manage these heterogeneous systems. However, such type of data is often difficult and time-consuming to obtain through field-based assessments alone. In light of this, the use of satellite imagery, largely unexplored in mountainous environments, may offer a scalable alternative to determine the agronomic indicator pastoral value (PV), a synthetic index integrating botanical composition, forage quality, palatability and productivity. In this study we tested a remote sensing-based approach to spatially and temporally model PV in semi-natural sub-alpine pastures of the Eastern Italian Alps (Mount Zoncolan, Udine, IT), evaluating its trend in relation to proxies of grazing intensity (topographic slope and distance from night barns). A total of 111 botanical field plots were collected across two cattle-grazed alpages (malga Tamai and malga Pozof) during the 2023-2025

growing seasons. Partial Least Squares (PLS) regression was applied to temporal composites of Sentinel-2 optical imagery and Google Embeddings, a novel multi-source satellite product integrating optical, radar and LiDAR data, to predict PV at 10 m spatial resolution. Trained models were subsequently applied to images from 2017-2018, reconstructing past conditions and assessing temporal trends in pasture quality. The models achieved satisfactory predictive performance (R^2 : 0.53-0.75; RMSE: 9.11-12.08), successfully discriminating lower-quality pastures (PV around 15) from more productive grasslands (PV > 25). Temporal comparisons indicated an overall reduction in PV between 2017-2018 and 2023-2025, consistent with the declining stocking rates and the documented expansion of shrub-encroached and lower quality pastures. As expected, more relevant PV decrease through time was detected in steeper areas, supporting the role of slope as a proxy for reduced grazing intensity, while no significant relationship was found for the distance from night barns, likely due to landscape fragmentation constraining livestock distribution and the coarse resolution of satellite images for detecting changes in relatively small and patched pastoral areas. The achieved results and the proposed approach demonstrate the potential of using satellite-based approaches as scalable and efficient tools to assess the spatial distribution and temporal dynamics of pasture quality, contributing to a more rational use of semi-natural forage resources and the preservation of valuable mountain agroecosystems.

Predicting AquaCrop-Simulated Durum Wheat Yield with Machine Learning: Algorithm Comparison and Agronomic Signal Convergence in the Capitanata Plain

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Abstract ID: 195

Session: 1. EFFICIENZA

Presentation: Poster

Durum wheat (*Triticum durum* Desf.) production in the Mediterranean basin faces growing climate variability, creating a demand for computationally efficient tools to support agronomic decision-making at regional scale. Process-based crop models such as AquaCrop provide mechanistically sound yield estimates but become computationally costly when screening large numbers of soil–climate–management combinations. This study addresses that constraint by developing and evaluating five machine learning (ML) surrogate models—Linear Regression (LR), Multilayer Perceptron (MLP), Support Vector Machine for regression (SMOreg), RandomTree, and Reduced Error Pruning Tree (REPTree)—trained to emulate the AquaCrop-GIS response surface for durum wheat grain yield across the Capitanata plain (Apulia, Southern Italy). A dataset of 342 instances was constructed by crossing 25 soil profiles, three sowing dates (early: 15 October; standard: 1 November; late: 15 November), and two irrigation regimes (rainfed; supplemental irrigation at anthesis) across 15 climatic grid cells over the 2014–2023 period. For each pedo-climatic cell $\times$ sowing date $\times$ irrigation combination, AquaCrop outputs were averaged over ten cropping seasons to yield a stable long-run productivity estimate, constraining the models to learn from the soil–climate–management feature space (22 predictors) rather than from temporal autocorrelation. All algorithms were implemented in WEKA 3.8.6 and evaluated by stratified 10-fold cross-validation. The MLP achieved the highest accuracy ($R = 0.983$; $R^2 = 0.966$; $RMSE = 0.083 \text{ t ha}^{-1}$), while the four interpretable models clustered in a narrow band ($R = 0.891\text{--}0.907$; $RMSE = 0.192\text{--}0.203 \text{ t ha}^{-1}$), separated by only 0.011 t ha^{-1} . The near-perfect MLP performance reflects the deterministic, noise-free nature of simulation-derived training data and establishes an accuracy ceiling against which the interpretable models are benchmarked. The accuracy cost of full transparency is therefore negligible in practice, supporting a use-driven criterion for algorithm selection: the MLP for high-precision spatial decision-support, LR or REPTree where predictions must remain explainable to farmers, advisors, or regulatory bodies. The central result is the robust convergence of agronomic signals across the five fundamentally different architectures (linear, kernel-based, tree-based). Standard sowing (1 November) yielded $+0.53 \text{ t ha}^{-1}$ over late sowing (15 November), supplemental irrigation at anthesis added $+0.17 \text{ t ha}^{-1}$, and fine-textured, less compacted soils consistently produced superior yields. The dominant climate signal—negative early-season (October–November) thermal

weights in SMOreg ($T_{\min}$: -0.462; $T_{\max}$: -0.405)—reflects AquaCrop’s phenological mechanism, whereby elevated autumn thermal loads accelerate development, compress canopy duration, and shift grain filling toward stress-prone late-season conditions. This cross-algorithm agreement constitutes a form of algorithm-independent validation, reinforcing the agronomic conclusions beyond any single modelling assumption and providing a reliable basis for sowing-date and irrigation guidance across the Capitanata plain and analogous Mediterranean environments.

Use of hyperspectral technology for precision toxic plant identification in Spinach

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Abstract ID: 197

Session: 1. EFFICIENZA

Presentation: Poster

Spinach (*Spinacia oleracea* L.) is an important horticultural crop widely consumed both fresh and processed. The increasing adoption of mechanical harvesting systems in spinach production has improved harvesting efficiency but also increased the risk of weed contamination during harvest operations. This issue is particularly critical in open-field cultivation systems, where toxic weed species such as *Datura stramonium* L. and *Datura metel* L. may be harvested together with spinach leaves due to their morphological similarity during early growth stages. These species contain toxic alkaloids, including scopolamine and hyoscyamine, and several intoxication cases associated with *Datura* species contamination have been reported in Europe and Italy. Therefore, the development of rapid and reliable methods for distinguishing toxic weeds from spinach plants is becoming increasingly important for food safety and precision agriculture applications. The aim of this study was to evaluate the potential of hyperspectral imaging technology for discriminating spinach from toxic *Datura* species. Spinach, *D. stramonium*, and *D. metel* plants were grown in pots under controlled conditions at the experimental farm "Lucio Toniolo" of the University of Padova. Approximately 70 hyperspectral images per species were acquired using a Specim IQ camera operating in the VNIR spectral range (400–1000 nm). Image acquisition was performed inside a dark chamber under controlled illumination conditions to minimize external light interference and ensure acquisition consistency. Reflectance values were extracted from manually selected leaf regions using Python-based scripts within a QGIS environment. Spectral data were subsequently analyzed using Principal Component Analysis (PCA), separability analysis, Welch ANOVA, and Cohen's d effect size estimation to identify the most discriminative spectral regions among species. Preliminary results revealed partial spectral overlap between the two *Datura* species, while spinach showed a more distinct spectral behavior. The most discriminative spectral regions were identified within the green region (540–560 nm) and especially within the red-edge region (700–730 nm), where highly significant differences among species were observed (Welch ANOVA, $p < 0.05$). PCA further highlighted

the importance of red-edge-related spectral features in species discrimination. These findings suggest that hyperspectral imaging represents a promising approach for the early detection and discrimination of toxic weeds in spinach cultivation systems, both in-field and during post-harvest processing. Further analyses will focus on expanding the spectral dataset and developing robust classification models for automated species recognition. This research was funded by the Italian Ministry of Health through the "PlanToxOmics" project (CUP: B23C23000650001).

Uptake and Translocation of Carbamazepine and Its Metabolites in Wastewater-Irrigated Tomato Plants

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Session: 1. EFFICIENZA

Presentation: Poster

The reuse of treated wastewater in agriculture is essential for sustainable water management amid global scarcity. However, the presence of pharmaceutically active compounds (PhACs) in this water source raises concerns regarding food safety and crop performance. This study investigates the uptake and translocation dynamics of the PhACs and their derivatives within the soil-plant system. Single tomato plants were cropped (from August 2025 to February 2026) into cylindrical polyethene pots (0.4 m diameter × 0.4 m high) filled with 12 kg of sandy clay loam soil. Two tomato hybrids, with indeterminate (Tomito) and determinate (Tayson) growth, were subjected to six irrigation treatments: a tap water control, tertiary wastewater (TW), and tap water spiked with a mix of six PhACs (carbamazepine, clarithromycin, climbazole, diclofenac, metoprolol, and telmisartan) at four concentrations: 1.0, 5.0, 50.0, and 100.0 $\mu\text{g L}^{-1}$. This abstract reports only the results relating to the behaviour of carbamazepine in the soil-plant system. The mean carbamazepine content values in the different matrices are shown in Figure 1. The irrigation treatments with a low concentration of PhACs (TW, Spiked1.0, and Spiked5.0) showed, as in the control, values close to the limit of quantification in the soil, roots, and fruit matrices; while the irrigation treatments with a high concentration of PhACs (Spiked50 and Spiked100) showed uptake in the roots and subsequent translocation to the stem, leaves, and fruit. The highest mean carbamazepine concentrations were detected in Spiked100 (about 100 ng g⁻¹) in the soil, roots (about 90 ng g⁻¹), stems (about 30 ng g⁻¹), leaves (about 150 ppb), and fruit (about 1 ng g⁻¹). Overall, the two tomato cultivars exhibited distinct behaviour in the uptake, translocation, and accumulation of carbamazepine across the various plant parts. On average, the indeterminate cultivar showed greater uptake and a greater capacity to translocate and accumulate this compound in the stem and leaves. This different behaviour may be due to differences in transpiration activity, which is characteristic of indeterminate tomato cultivars. Carbamazepine's parent compounds (3-hydroxycarbamazepine, 10,11-epoxycarbamazepine, and 10,11-dihydro-10,11-dihydroxycarbamazepine) showed distinct behaviours in translocation and subsequent accumulation across various plant matrices and soil (result not shown). The significant aspect was

the absence ($<LOQ$) of the parent compounds in the edible part of the tomato (fruit), even at the high-concentration treatments (Spiked50 and Spiked100). These results suggest that at a typical concentration of carbamazepine in wastewater ($0.2-0.4 \mu\text{g L}^{-1}$), the risk of this pharmaceutical entering the food chain is negligible. However, the indeterminate cultivar's higher uptake capacity highlights the important influence of genetic and physiological traits on contaminant dynamics, necessitating cultivar-specific risk assessments for wastewater reuse. Future research should extend this evaluation across multiple crop cycles, various environmental conditions, and additional pharmaceutical compounds to better understand the fate of PhACs and their metabolites in the soil-plant system. This study was funded by the Ministry of Education, University and Research (Italy), grant number P2022PY45N. Project: Sustainable use of treated urban wastewater in agriculture: study of the fate of pharmaceuticals and their respective metabolites in the soil-plant system (WESTiUSE).

BioForge® biostimulant improves crop stress resilience in sunflower, wheat and corn under field and controlled drought conditions

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Session: 1. EFFICIENZA

Presentation: Poster

ABSTRACT: Biotic stress from climate extremes, especially drought, increasingly threatens crop productivity. Biostimulants offer a novel approach to bolster plant resilience. BioForge (AGH-6-1) is a mineral-based biostimulant designed to mitigate abiotic stress effects through antioxidative and hormonal regulation. This study aimed to evaluate BioForge's efficacy in enhancing crop performance under stress conditions. Multi-environment field trials were conducted in Europe (2025) on sunflower, winter wheat, and corn, along with a controlled-environment drought assay on. Treatments included foliar BioForge (0.5–1.0 L/ha, single or split applications) versus untreated control. Key metrics, grain yield, NDVI (canopy greenness index), seed quality, and stress physiology (e.g. electrolyte leakage), were measured. ANOVA with LSD separation was used to determine significance of treatment effects. BioForge consistently led to improved stress outcomes across crops. In winter wheat, two BioForge applications increased grain yield by 4.3% over control (significant overall, $p < 0.05$; site-specific significance at one location). Sunflower sprayed with BioForge showed higher mid-season NDVI and a modest yield uplift (+3%) vs untreated (not always statistically distinct). In corn, BioForge plots, maintained yield levels across diverse rainfall conditions, with NDVI benefits in drier sites. Under severe drought in growth-chamber peppers, BioForge reduced leaf electrolyte leakage by 21% (indicating reduced cell damage) and maintained greater leaf area. BioForge application improved plant stress tolerance and stabilized yields under water-limited conditions. These findings support BioForge's use as a climate adaptation tool to enhance crop resilience and yield stability in sustainable farming systems. **KEYWORDS:** biostimulant; drought stress; NDVI; yield stability; foliar application; sustainable agriculture

A Smartphone-Based Method for Estimating Crop Green Cover

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Session: 1. EFFICIENZA

Presentation: Poster

Recent studies have demonstrated the possibility of obtaining an acceptable estimate of weed development by simply subtracting the crop green cover from the total green cover measured in a sufficiently high-resolution RGB image. The accuracy of this approach inevitably depends on the correct quantification of the crop green component, which represents a crucial step in model calibration. However, establishing experimental plots specifically for this purpose increases the time and resources required, thereby limiting the widespread adoption of the method at the farm level. For this reason, the present study evaluated the possibility of estimating the average green cover of individual plants through random sampling and image acquisition using a standard smartphone. This approach offers the dual advantage of reducing the time and costs associated with model calibration while providing a more accurate estimate of the measurement error. To correctly quantify individual plant cover, two main aspects were addressed: (i) the use of a reference frame of known dimensions equipped with geometric markers to enable accurate scale recovery under field conditions; and (ii) the application and integration of computer vision techniques, including target recognition, camera calibration, and image rectification, to transform smartphone photographs into true-scale images from which crop green cover can be quantified. The experiment was conducted from October to November 2025 in the greenhouse of the Department of Agriculture, Food and Environment at the University of Pisa. A total of eight pots were prepared and sown on 20 October 2025 using a single commercial maize hybrid (Pioneer P1541, FAO class 600). Image acquisition started at seedling emergence and continued until plants reached the 4–5 leaf stage. All images were captured using the camera of a Samsung Galaxy S10+ smartphone (Model SM-G975U). Initially, images were acquired three times per week and subsequently reduced to twice per week as canopy expansion slowed. Images were taken from a zenithal (top-view) position, with slight variations in camera angle to assess the robustness of marker detection. Plant area was estimated by summing the total number of pixels classified as vegetation in the binary mask. The pixel count was then converted into physical units (mm^2) using a calibrated scaling factor (i.e., the area per pixel) derived from the image rectification process, thereby providing the total green surface area for each sampled image. The results showed that segmentation performance was highly dependent on the selected threshold

value. Likewise, the positioning analysis demonstrated that even small variations in camera angle, distance, or centring could significantly affect the estimated green cover, highlighting image acquisition geometry as a major source of measurement variability. These preliminary findings emphasize the importance of standardized image acquisition procedures and careful calibration of image-processing parameters to obtain reliable estimates of crop green cover.

Sulfur supplementation in wheat: agronomic performance and implications for spike traits

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Abstract ID: 219

Session: 1. EFFICIENZA

Presentation: Poster

Common wheat (*Triticum aestivum* L.) is one of the most widely cultivated staple crops in Italy; however, national production satisfies only a fraction of domestic demand. Cereal-based systems are increasingly exposed to market fluctuations affecting production costs and supply stability, with potential implications for food security in import-dependent countries. In this context, improving wheat productivity and resource-use efficiency is essential. Although sulfur (S) is a key macronutrient, it is often overlooked in nutrient management. In wheat, S fertilization can enhance yield, grain quality, and fertilizer-use efficiency. Despite extensive research on S-fertilization, morpho-physiological mechanisms underlying wheat responses remain poorly understood. In particular, studies on spike fertility have mainly focused on genotype, photoperiod, temperature, and nitrogen nutrition, while the role of sulfur has received little attention. Given the central role of wheat in global food security, agronomic research should both evaluate management practices and improve our understanding of the mechanisms controlling yield formation. Mesocosm trials were conducted during 2024 and 2025 growing seasons at the experimental Centre of the Department of Agriculture, Food and Environment of University of Pisa, Italy, using the commercial variety 'Bologna'. Cultivation was carried out in semi-controlled facility constituted by growth boxes (50 x 50 cm, and 40 cm depth) set up in open-air conditions, filled with loam soil. The treatments consisted in five fertilization strategies: "T0" = unfertilized control; "T1" = 150 kg N ha⁻¹; "T2" = 150 kg N ha⁻¹ + 30 kg S ha⁻¹; "T3" = 112 kg N ha⁻¹; "T4" = 112 kg N ha⁻¹ + 30 kg S ha⁻¹. Sulfur was applied prior to sowing using calcium sulfate recovered from an industrial waste stream. At harvest, biomass allocation and yield components were measured. For each box, ten plants were randomly selected for "mapping" the spike. Briefly, after recording the number of sterile and fertile spikelets, individual spikelets were separated maintaining their original position on the spike and subsequently dissected to separate fertile florets. Each kernel was then weighted with an analytical scale, maintaining their position into the spikelet, allowing to determine the kernels number and weight distribution for each spikelet and within the spike. Moreover, agronomic efficiency of nitrogen fertilization (AE) was computed. Among T1 and T2, no differences in grain yield were observed, while T4 strategy increased wheat yield on average by 17% compared to T3, reaching yield equal to the higher N rates. Good productive performances together with reduced N application allowed T4 to increase AE on average by 8.6 kg seed kg N applied⁻¹ compared to the other strategies. Analysis of spike mapping highlighted a significant interaction among position and fertilization strategy. Yield components analysis showed that sulfur increased wheat productivity mainly by improving spike fertility, enhancing floret

survival and kernel set at distal positions in the spikelet. As no differences in phenological development were observed among treatments, this effect was likely due to faster development at these positions. Overall, sulfur fertilization from recovered sources appears to be a valuable strategy for sustainably increasing wheat yield while improving fertilizers use efficiency.

Evaluating data assimilation techniques for improving grassland growth model simulations

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Session: 1. EFFICIENZA

Presentation: Poster

Accurate estimation of grassland productivity is essential for supporting sustainable grazing management, optimizing forage utilization, and assessing ecosystem responses to environmental variability. Grassland growth models, based on Leaf Area Index (LAI) as key driver to simulate above-ground biomass (AGB), are used to support management decisions. However, their performance is constrained by uncertainties in model parameterization and input data availability. Remote sensing (RS) observations, providing critical information on vegetation status, have been widely recognized as an effective means of improving model simulations through data assimilation techniques. Within this framework, this study evaluates diverse approaches to assimilate satellite-derived LAI data, aiming to enhance AGB simulations in an agro-pastoral system. The study was conducted in a sown pasture located in Borgo San Lorenzo (43.96°N, 11.39°E; Tuscany, Italy). At this site, field LAI, measured with a ceptometer (LP-80 Meter), and AGB dry weight were collected on a monthly basis (every ~28 days) throughout the 2020-2022 growing seasons. Sentinel-2 images were acquired during the 3 years and the BIOPAR LAI product (VITO) was used as satellite input, preprocessed through quality screening and gap-filling, and calibrated against field-measured LAI to generate a continuous daily time series. These LAI data were assimilated into a semi-mechanistic model (GRASSVISTOCK) designed to simulate biomass accumulation in agro-pastoral systems. The framework for data assimilation in GRASSVISTOCK included four approaches: (i) classical model calibration against field-observed LAI; (ii) model forcing, in which RS-derived LAI was used to force the model at daily time steps; (iii) model updating, where LAI observations were used to update the simulated states; and (iv) parameter re-calibration using satellite data to optimize the most sensitive model parameters, identified through a previous sensitivity analysis. The model was then validated

against field-observed AGB data. Preliminary results show that different data assimilation methods affected model performance in reproducing AGB dynamics. The calibration approach achieved the highest correlation with observations ($r = 0.82$), but showed relatively high errors ($\text{RMSE} = 56.03 \text{ g m}^{-2}$) and negative model efficiency ($\text{NSE} = -0.20$), indicating limited predictive skills. The forcing approach provided the best overall performance, with the lowest RMSE (42.13 g m^{-2}) and positive NSE (0.17), despite a lower correlation ($r = 0.56$; Fig. 1). The updating approach performed less effectively ($r = 0.48$; $\text{RMSE} = 69.14 \text{ g m}^{-2}$). Re-calibration improved correlation ($r = 0.80$) compared to forcing, but model efficiency remained negative ($\text{NSE} = -0.13$), indicating limited gains in predictive accuracy. These findings suggest that the model was unable to adequately reproduce the variability observed in the satellite-derived LAI. The forcing-base assimilation incorporated this information into the simulations, improving state estimates and reducing prediction errors. Parameter recalibration enhanced seasonal dynamics simulations but failed to reduce significantly model uncertainty.

Intraspecific variation in germination response to salinity differentiates winter- and spring-type accessions of *Camelina sativa*

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Abstract ID: 228

Session: 1. EFFICIENZA

Presentation: Poster

Camelina sativa (L.) Crantz is an emerging oilseed crop for cultivation on saline marginal land, but intraspecific variation in germination response to salinity and its association with biotype (winter vs. spring) remains poorly understood. This study screened 83 camelina accessions, including 72 spring-type and 11 winter-type genotypes, to assess whether biotype influences germination performance under salinity. Seeds were germinated at 0 and 200 mM NaCl, and 6 stress tolerance indexes (STIs) were calculated as the ratio of values observed under salinity to values observed under control conditions: total germination (TG), normality rate (NR), germination index (GI), velocity coefficient (VC), mean germination time (MGT) and germination synchrony index (GSI). Principal Component Analysis explained 80.8% of the total variance (PC1 = 54.2%, PC2 = 26.6%). Hierarchical k-means clustering classified the accessions into four phenotypic groups: Cluster 1 (n=41), high but delayed germination; Cluster 2 (n=13), moderate germination with the highest synchrony index under salinity STI GSI (1.76); Cluster 3 (n=10), optimal germination performance with the highest STI TG (0.98), STI NR (1.00) and STI GI (0.73); and Cluster 4 (n=19), with impaired germination across all indices. Out of the 11 winter-type accessions, three were classified in Cluster 1, five in Cluster 2, three in Cluster 3, and none in Cluster 4, accounting for 7%, 38%, 30% and 0% of each cluster, respectively. Winter-type genotypes were therefore proportionally most represented in Cluster 2 and Cluster 3, and entirely absent from Cluster 4. Among them, the three accessions classified in Cluster 3 stood out for showing the highest STI values across all the considered indexes. Overall, these findings suggest that winter-type camelina exhibits distinct germination behaviour under salinity compared to spring ones, although further studies on a larger panel and at later developmental stages are needed to confirm and extend these observations.

Performance of drought tolerant maize hybrids in two on-farm experiments in northeastern Italy

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Abstract ID: 229

Session: 1. EFFICIENZA

Presentation: Poster

Future climate change is projected to increase the severity of its impacts on natural and human systems. The most recent IPCC report (2023) identifies drought as one of the most relevant abiotic stressors in the Mediterranean region of Europe with high-confidence projections of increased drought events under both 1.5°C and 4°C global warming scenarios. In all scenarios, maize yields are expected to decline in major production areas. In fact, Italy reported yield declines of about 10 t/ha in the 2024 growing season and a 42% decrease in the area dedicated to maize production between 2006 and 2023. This is not different for the Friuli Venezia Giulia region that holds about 10% of the Italian maize production and face a decrease both in surface (-59%) and yield (-79%) since 2012. With this climate change context and with the objective to address a sustainable and efficient use of water for maize production, the AGRITECH project together with farmers, co-created on farm experiments (OFE) targeting smart maize production. These experiments tested maize hybrids tolerant to drought (DT) and compared their productivity with relative conventional (C) materials under irrigation and rainfed conditions. Two OFEs were established in 2025 at the locations of Colloredo di Monte Albano and San Vito al Tagliamento. In the OFE of Colloredo di Monte Albano, under rainfed conditions and a randomized plot design with four replicates, we tested DT and C hybrids of medium maturity class (FAO 500). No significant differences were observed between DT and C hybrid yields (19.5 and 18.8 t ha⁻¹ at 25% DM respectively) or grain quality (thousand seed weight, protein, starch, fat and mycotoxins in grain). At the location of San Vito al Tagliamento, we tested semi-early maturity class (FAO 400) DT and C hybrids under irrigated (I) and non-irrigated (NI) conditions in a split plot design with irrigation levels as main plots and five replicates. In this location, similar results with lower yields were observed. There were no significant differences between the DT and C hybrids in both irrigation levels (9.9 t ha⁻¹ for DT and 11.5 t ha⁻¹ for C hybrid). Considering the same growing season year; pedoclimatic conditions were the key factor in determining maize yield. Although DT hybrids did not outperform C hybrids, they showed a stable response that merits further study.

Irrigation decisions based on Support System: a comparison of commercial DSS

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Session: 1. EFFICIENZA

Presentation: Poster

Agriculture is currently facing rapidly evolving scenarios, because of the increasing economic constraints and impacts of climate change. Digitalization can help farmers in the management of their farm. An important aspect of digitalization is the use of Decision Support Systems (DSSs), available to support farmers from many points of view, among them for managing irrigation. In Italy, both commercial and public DSSs are widely used in fruit and vegetable production systems (both greenhouse and open field), whereas their adoption remains limited for arable crops. One of the main limitations of existing systems is that they generally focus only on irrigation scheduling recommendations. Another critical limitation is their limited adaptability to surface irrigation systems, which are still widely adopted in the Po plain, where irrigation management ruled by irrigation consortia constrains water availability. This study aims to compare and analyse five DSS including four commercial and one public, to identify strengths and limitations. The different DSSs were tested on 16 fields across 7 mixed crop-livestock farms in the Province of Cuneo, under irrigation systems including surface irrigation, central pivot system, drip irrigation, and sprinkler irrigation. Irrigated crops were mainly maize and meadows. The systems were compared in terms of ease of use, information completeness, and time required for data management. Special attention was given to the following aspects: input of territorial and crop management data; description of crop cycles and crop succession; irrigation scheduling criteria; availability of satellite vegetation indices indicators; indicators for comparing irrigation scenarios or agricultural years; and collection and storage of farm data. The comparison between the studied DSS is presented following the main sections. In the “Home” section, the visual component was predominant: users can access farm data, crop allocation within different fields, and recent harvests. The “Map” section allowed users to locate sensors, weather stations, and field plots, while the “Field Information” section displayed historical, current, and field-measured data specific to each plot. Additional sections focus on soil and meteorological data. A dedicated satellite provided detailed visual information through colour variations, enabling users to identify crop vigour and low-productivity zones with high precision. Within the “Irrigation and Crop Management” section, users can record irrigation events and plan

future ones. The DSSs generate recommendations about the optimal irrigation volume and the best timing for irrigation applications. At the same time, the “Crop Development Models” section allowed users to record field observations and monitor the crop growth over time. Regarding outputs, the “Water Balance” section included both graphical and numerical representations of irrigation and soil water dynamics. Finally, the DSSs included performance indicators considering environmental and economic aspects. Even if all the analysed DSSs provided all the information described above, the main differences found are related to the ease of use and data interpretation, detail of information required, the possibility of analysis of past data, and performance indicator reporting.

Foliar selenium and sulphur fertilization improves grain quality traits in bread wheat under Mediterranean rainfed conditions

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Presentation: Poster

Improving grain nutritional value and technological quality while maintaining stable yields is a major challenge for wheat production systems in Mediterranean environments. Foliar fertilization with selenium (Se) and sulphur (S) has emerged as a promising agronomic strategy to enhance grain composition through the modulation of protein fractions, reduction of anti-nutritional compounds, and improvement of micronutrient bioavailability. This study evaluated the effects of Se and S foliar applications on agronomic performance, grain quality and nutritional traits of bread wheat grown under rainfed Mediterranean conditions. A two-year field experiment was conducted in Cesa (Marciano della Chiana, Tuscany region, Italy) during the 2020–2021 and 2021–2022 growing seasons using a split-split-plot design. Two bread wheat cultivars were evaluated: the modern cultivar ‘Bologna’ and the old cultivar ‘Sieve’. Selenium was applied as sodium selenite at five rates (0, 2.57, 5.14, 10.27 and 20.54 g ha⁻¹) at watery ripe stage, while sulphur was supplied as wettable sulphur at three rates (0, 3.2 and 6.4 kg S ha⁻¹) at booting. Grain yield, protein concentration and protein fractions, starch concentration, free asparagine, phytic acid, phytic-acid-to-mineral molar ratios and dough rheological parameters were determined and analysed using mixed-effects linear models. Grain yield was primarily influenced by genotype and seasonal conditions and was not significantly affected by Se or S fertilization, indicating that quality improvements were achieved without yield penalties. Bologna showed a 6.0% higher protein concentration than Sieve, whereas Sieve exhibited a 34.1% greater thousand kernel weight. Free asparagine concentration was strongly affected by sulphur supply, which explained 72.1% of the observed variability. Increasing S from 0 to 6.4 kg ha⁻¹ reduced free asparagine by 82.7% (from 24.9 to 4.32 μmol g⁻¹ DW), highlighting the importance of S nutrition in mitigating acrylamide precursors. Selenium further contributed to free asparagine reduction, particularly under adequate S availability, confirming a synergistic interaction between the two nutrients. Phytic acid concentration was mainly genotype-dependent, with Sieve accumulating 45.7% more phytic acid than Bologna. However, Se fertilization reduced phytic acid by 10.1% and substantially improved mineral bioavailability indicators. Compared with the untreated control, the highest Se rate reduced Phy:Se molar ratio by 81.9%. Selenium application also

decreased Phy:Cu, Phy:Fe, Phy:Mn and Phy:Zn molar ratios, suggesting an increased potential bioavailability of these essential micronutrients. Sulphur fertilization markedly modified protein composition, decreasing gliadin concentration by 10.4% while increasing glutenin and total gluten by 20.7% and 6.1%, respectively. These changes improved the gliadin-to-glutenin balance and were accompanied by a slight increase in dough strength. The results of this study demonstrate that targeted foliar Se and S fertilization can enhance nutritional and technological grain quality without compromising productivity, supporting the development of sustainable and quality-oriented wheat production systems under Mediterranean rainfed conditions.

Multi-scale soil moisture monitoring in durum wheat: integrating point sensors, cosmic-ray neutron sensing and satellite-oriented observations in the Rieti Plain

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Presentation: Poster

Soil moisture is a key variable for interpreting crop growth, water availability and within-field variability in rainfed cereal systems. However, its monitoring in agricultural fields is strongly affected by the spatial scale of observation. Point sensors provide detailed information at specific locations and depths, whereas proximal and remote sensing approaches offer more spatially integrated information. Bridging these scales is essential to improve agronomic interpretation of soil water dynamics and to support future applications in crop modelling, precision agriculture and satellite-based soil moisture monitoring. This study presents a multi-sensor experimental platform established in a 20 ha winter wheat field in the Rieti Plain, Central Italy. The platform was designed to monitor soil moisture dynamics across different spatial and vertical scales. Five elementary sampling units of 30 × 30 m were selected in areas characterized by contrasting soil and vegetation conditions. Within each unit, five Stevens HydraProbe sensors were installed at 0–10 cm depth, for a total of 25 near-surface sensors. Additional Sentek Drill & Drop probes were installed to monitor soil moisture at 20, 30 and 40 cm depth. A Finapp cosmic-ray neutron sensing probe was placed near the centre of the field to provide field-scale soil moisture estimates over an intermediate footprint of several hectares. A weather station located at the field edge records rainfall and meteorological variables, while repeated agronomic measurements, including biomass, crop water content and leaf area index, are collected during the growing season. The integrated monitoring design allows comparison between rainfall events, near-surface soil moisture response, deeper profile dynamics and field-scale soil water patterns. Preliminary observations highlight the complementary role of the different measurement systems: point sensors describe rapid changes in the upper soil layer and vertical redistribution after rainfall, while the cosmic-ray neutron sensing probe provides a spatially

integrated signal that is more representative of field-scale water availability. The experimental set-up also provides a ground reference framework for future comparison with high-resolution satellite soil moisture products. Overall, the platform represents a useful approach for characterizing soil moisture dynamics in cereal cropping systems by combining point, proximal and satellite-oriented observations. Its main agronomic value lies in the possibility of linking soil water availability with crop development, field variability and future site-specific management strategies. The dataset will also support the calibration of crop models and the validation of remote sensing products for agricultural applications.

Development and Validation of an Autonomous Mower-Based Imaging System for Precision Turfgrass Health Monitoring

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Presentation: Poster

Precision turfgrass management increasingly relies on remote sensing technologies to assess plant health, optimize nutrient inputs, and improve sustainability. Traditional monitoring approaches, including handheld sensors and unmanned aerial vehicles (UAVs), provide valuable information but often require dedicated field operations, specialized personnel, and periodic data collection. The integration of sensing technologies into routine maintenance equipment offers an opportunity to automate data acquisition and enable continuous monitoring of turfgrass conditions. The objective of this study was to develop and validate an autonomous image-based sensing system mounted on a robotic mower for the assessment of turfgrass health and nitrogen status. The trial was conducted in June 2026 at a sod farm in Pisa, Italy (43° 39'N 10° 21'E, 2 m a.s.l.). The selected species was a hybrid bermudagrass (*Cynodon dactylon* × *C. transvaalensis* 'Tahoma 31'). To generate a wide range of turf responses, a linear nitrogen gradient was established using twentyone fertilization rates ranging from 0 to 480 kg N ha⁻¹, applied as ammonium sulphate ((NH₄)₂SO₄). The experimental area measured 260 m² (10 x 26 m) with four replications. An autonomous mower (Husqvarna Automower EPOS 550) was equipped with a Raspberry Pi-based sensing unit consisting of an RGB camera, GPS receiver, power supply, and wireless communication module (4G). The Raspberry Pi hosted a local HTTP server that streamed real-time video from the onboard RGB camera. Researchers accessed the video feed remotely through a web browser and captured images directly on a computer for subsequent analysis. Specifically, images were processed through Digital Image Analysis (DIA) using TurfAnalyzer software to extract Dark Green Color Index (DGCI), which is strongly correlated with turfgrass vigor and canopy greenness. To validate the proposed system, DGCI values obtained from the mower-mounted camera were compared with measurements collected using established sensing technologies. Ground-based assessments included Normalized Difference Vegetation Index (NDVI) measurements acquired with a GreenSeeker handheld active optical sensor (model 505, Trimble Corp., Sunnyvale, CA, USA). Aerial assessments were performed using UAV-mounted RGB imagery processed through DIA as well. Correlation analyses were conducted to investigate relationships among mower-derived DGCI, drone-derived DGCI and GreenSeeker NDVI. The

proposed approach aims to provide a fully autonomous, non-destructive, and scalable solution for turfgrass monitoring. By integrating sensing capabilities directly into routine mowing operations, the system enables continuous data collection without additional field interventions, increasing temporal monitoring frequency.. The system is expected to support the adoption of precision management strategies in turfgrass systems and demonstrate the potential of robotic maintenance equipment as a practical tool for real-time decision support in sports turf and landscape management.

Performance of Proso Millet as an Intermediate Crop under Different Water Regimes and Nitrogen Levels.

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Session: 1. EFFICIENZA

Presentation: Poster

The escalation of global climatic issues and the scarcity of water resources necessitate resilient, low-environmental-impact crops capable of tolerating abiotic stresses. This is critical within the Mediterranean Basin, which is widely regarded as a global warming and drought hotspot. The objective of this study is to evaluate the agronomic and physiological performance of proso millet (*Panicum miliaceum* L.) grown as a summer intermediate crop in a sequential cropping system following wheat, under high and low fertilisation regimes, and high and low irrigation regimes. The field experiment was conducted in 2025 at the Aqua Campus experimental farm on sandy soil. Sowing was performed on July 1st at a seeding rate of 18 kg/ha. The experiment adopted a randomised complete block design with two irrigation regimes and two nitrogen rates (45 vs 60 kg N/ha). Irrigation treatments included conventional irrigation guided by Irriframe's (IR) Decision Support System irrigation advice and a drought strategy limited to a rescue application for the crop's emergence (Rainfed). During the crop cycle, canopy development was monitored with a ceptometer to measure light interception, while the relative chlorophyll content was evaluated through SPAD index readings. At harvest, final production parameters were determined, including total biomass yield, grain yield, and 1000-seed weight. The ANOVA on early monitoring data revealed no statistically significant differences ($p > 0.05$) in light interception and chlorophyll (SPAD) between the two water regimes and two nitrogen levels. Total biomass yield was also statistically unaffected by water management and nitrogen rates, maintaining a stable yield of 6.2 t/ha. Grain yield showed statistically significant differences ($p < 0.05$). The highest grain yield occurred under the Rainfed + 45 kg N/ha treatment, 1.8 t/ha, which was significantly outperforming the IR + 45 kg N/ha and Rainfed + 60 kg N/ha combinations. Furthermore, the IR + 60 kg N/ha treatment exerted a negative, while non-significant, effect on yield due to lodging and delayed maturity. The IR + 60 kg N/ha treatment resulted in an intermediate grain yield, remaining statistically comparable to all other treatments. Regarding 1000 seed weight, the Rainfed + 60 kg N/ha treatment achieved the highest grain weight of 6 g, performing significantly better than the Rainfed + 45 kg N/ha and IR + 60 kg N/ha combinations. Rainfed conditions caused a higher average WUE compared to irrigated treatments (0.94 vs. 0.53 t ha⁻¹mm⁻¹). Interaction analysis revealed that the Rainfed + 45 kg N/ha treatment achieved the highest water efficiency (1.01 t ha⁻¹mm⁻¹). These findings classify proso millet as an

efficient low-input crop; however, the growing season featured erratic yet abundant rainfall (179 mm), which nevertheless allowed the crop to maintain stable biomass and grain yield under unirrigated conditions. Furthermore, while higher nitrogen rates did not increase grain yield, they exerted a significant influence on the 1000-grain weight, highlighting a trade-off in resource allocation that enhances seed size. These results suggest that proso millet represents a potential crop for sustainable agriculture, sustaining stable production and yield efficiency under combined water and nutrient stress in Mediterranean farming systems.

Precision N scheduling in open-field onion cultivation: Evaluating algorithm-based N-VRA and crop simulation model prediction

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Session: 1. EFFICIENZA

Presentation: Poster

Nitrogen management remains a major challenge in onion production due to its shallow root system and low nitrogen recovery. Conventional fixed-rate nitrogen application schedules often fail to account for crop demand and field variability, resulting in inefficient nitrogen utilization. This mismatch reduces nitrogen use efficiency (NUE), limits crop productivity, and increases environmental nitrogen losses. Adaptive nitrogen management strategies are needed to improve both crop performance and sustainability. Recent advances in precision agriculture, including variable-rate nitrogen application (N-VRA) and crop simulation models, have been widely developed and applied in, e.g., cereal crops to enhance N management and decision-making. However, their application to specialty and high-value crops such as open-field onion remains insufficiently explored. To address this gap, an N-VRA strategy was recently developed by integrating crop growth, the critical nitrogen dilution concept, and NDVI-based sensing approaches. This approach tends to prescribe higher N inputs in areas with lower vegetative vigor and greater stress. However, it does not account for inherent soil fertility constraints that may contribute to N losses. In contrast, process-based crop simulation models can capture crop growth and N dynamics and predict site-specific yield responses, although their effectiveness depends on the availability of suitable crop-specific models. The objectives of this study were: (i) to compare two newly implemented N-VRA methods for open-field onion cultivation based on process-based crop modelling and crop-specific on-the-go N-VRA strategies; (ii) to determine the optimal variable fertilizer N rates for side-dress applications. The experiment was conducted during 2025 and 2026 growing seasons at a commercial farm specializing in Borettana onion production in the southern Verona province. Measured variables included crop growth dynamics, N uptake, leaf area index, bulb yield, NUE, and cumulative NO_3^- -N leaching, which

was quantified using anion-exchange resin samplers installed below the root zone. The N-VRA strategies were based on: (i) a schematic framework for on-the-go N-VRA tailored to Borettana onion, integrating biomass estimation, optimal N prediction, and NDVI-derived crop N status; (ii) the newly implemented CSM-CROPGRO-Onion model within the process-based DSSAT framework. Optimal N rates were identified using a multi-criteria approach that simultaneously maximized bulb yield and economic return while maintaining high N uptake. Each strategy was evaluated under two liquid N application frequencies representing the farmer's business-as-usual practice (five split applications) and a high-frequency strategy (ten split applications). These treatments were compared with fixed-rate N inputs, low-input, and zero-input controls to assess NUE. Preliminary results showed that both N-VRA strategies well predicted seasonal crop growth, N uptake, and crop N demand. The CSM-CROPGRO-Onion-based approach differentiated N inputs according to application frequency, indicating differences in N-use efficiency that were supported by nitrate leaching data. In contrast, the NDVI-based approach exhibited lower sensitivity and recommended similar N inputs regardless of application frequency. Overall, this research contributes to the development of adaptive N management frameworks that integrate N-VRA and crop simulation modelling to improve yield, enhance NUE, and reduce environmental N losses for open-field onion production systems.

Linking controlled and field drought responses in *Camelina sativa*: seed number as a conserved yield trait

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Presentation: Poster

Increasing drought frequency and irregular rainfall constrain crop production in low-input systems where irrigation options are limited. Crop diversification requires species able to maintain productivity under uncertain water availability. *Camelina sativa* is a promising oilseed crop because of its short cycle, flexible phenology, and ability to fit different sowing windows. However, this flexibility means drought effects depend on how crop development aligns with seasonal water availability. Water limitation during flowering and seed development is relevant for genotype evaluation because it can directly affect yield formation. Controlled experiments allow drought timing and intensity to be defined precisely, supporting identification of mechanisms involved in stress response. However, field drought is heterogeneous and cannot be assumed from weather alone. This makes it difficult to link controlled responses with agronomic performance and to identify genotype traits conserved across conditions. This study integrated camelina lysimeter and field drought responses by testing whether genotype differences were conserved across systems and stress conditions. Four lines (UNT4, UNT18, UNT21, and UNT46) were evaluated in a lysimeter experiment under well-watered and after-flowering drought treatments, and in randomized block field trials in Italy and the UK. Field trials were selected because seasonal patterns indicated post-flowering water limitation. To verify whether this potential stress was expressed by plants, physiological traits measured after flowering were integrated into a stress index using standardized z-scores. The stress index showed that the UK field trial expressed responses comparable to the lysimeter drought treatment, whereas the Italian field trial resembled the lysimeter well-watered treatment. This enabled a System $\times$ Stress $\times$ Line analysis, where System separated lysimeter and field experiments, Stress separated drought-associated and non-stress-associated responses, and Line tested genotype-specific behavior. Physiological traits were strongly system-dependent, indicating that controlled and field environments did not induce equivalent plant responses. In contrast, productivity traits showed stable genotype responses across systems. Under drought-associated conditions, UNT21 and UNT46 achieved higher seed yield and oil yield than UNT4 and UNT18, although UNT4 and UNT18 showed higher thousand kernel weight. Seed number per plant explained this contrast more clearly than seed size. Under drought-associated conditions, seed number increased in UNT21 and UNT46 but decreased in UNT4 and UNT18 compared with non-

stress conditions. This trait showed a significant Stress $\times$ Line response, with no significant System effect or System interaction, indicating conserved line differences in seed number regulation across lysimeter and field trials. These results identify seed number regulation as a key trait for camelina adaptation to water limitation after flowering. Lines maintaining or increasing seed number under drought-associated conditions sustained higher seed and oil yield, whereas higher thousand kernel weight alone did not translate into better yield performance. By combining imposed drought, selected field environments, and a physiological stress index, this study separated potential water limitation from plant stress. This approach identified conserved genotype differences across systems and highlighted seed number maintenance for improving camelina performance in drought-prone systems. Future work should clarify mechanisms enabling seed number maintenance under post-flowering drought and test stability across broader genetic diversity and sowing windows.

Agronomic performance of durum wheat cultivars and varietal mixtures under Mediterranean field conditions prone to abiotic stress

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Session: 1. EFFICIENZA

Presentation: Poster

Durum wheat production is largely concentrated in the Mediterranean region, an area projected to be severely affected by climate change and increasing abiotic factors. Extreme rainfall events, temporary waterlogging, and drought periods may negatively impact crop productivity and yield stability. Identifying resilient cropping systems is therefore a major research priority. In this context, cultivar selection and crop diversification strategies, including the use of varietal mixtures, may contribute to improving the resilience of durum wheat-based cropping systems. The Improving Resilience to Multiple Abiotic Stresses (IRMA) project aims to identify sustainable and eco-friendly approaches to improve durum wheat adaptation to current and future environmental challenges. IRMA is funded by the Italian Ministry of University and Research through the PRIN 2022 programme (Project IRMA, Grant No. 2022NWZJNP). A field experiment was conducted in Central Italy over two consecutive seasons (2024-2025 and 2025-2026) on two contrasting soil types (sandy and loam) to compare the agronomic performance of different durum wheat cultivars and varietal mixtures under different environmental conditions across the crop cycle, particularly in relation to soil water availability. Eight durum wheat cultivars representing different breeding periods (i.e., old, intermediate, and modern) and agronomic characteristics were evaluated: Senatore Cappelli, Saragolla, Svevo, Claudio, Emilio Lepido, Dylan, Inizio, and Prossimo. Moreover, four varietal mixtures combining selected cultivars were assessed as a crop diversification strategy. In each growing season, the experiment was carried out in a randomized complete block design with three replications. At maturity, crop yield and yield components were assessed through destructive sampling. Preliminary results from the first year indicated substantial variability among cultivars and varietal mixtures for all measured productive traits, except for spike number (Table 1). Grain yield differed markedly among cultivars, with the highest values observed in Prossimo, Inizio, Saragolla, and Emilio Lepido. In contrast, Senatore Cappelli and the varietal mixtures Mix 3 (Cappelli,

Inizio/Svevo) and Mix 4 (Cappelli/Inizio/Svevo/Emilio Lepido) showed lower grain yield (Figure 1). Intermediate performances were recorded for Claudio, Svevo, Dylan, Mix 1 (Inizio/Emilio Lepido), and Mix 2 (Inizio/Emilio Lepido/Svevo). Traditional cultivars generally exhibited greater vegetative biomass, whereas modern cultivars tended to show higher efficiency in allocating biomass to grain formation (Table 2). Varietal mixtures displayed intermediate responses and, in several cases, appeared to combine favorable traits of their component cultivars. Ongoing statistical analyses, together with the results from the second growing season, will allow the identification of the most promising cultivars and mixtures for sustainable durum wheat production systems under variable soil water conditions. These findings will contribute to the development of agronomic strategies aimed at enhancing crop resilience to abiotic stress. The observed variability confirms the importance of genotype selection as a key factor influencing crop productivity under varying field conditions. Moreover, the inclusion of varietal mixtures highlights the potential of crop diversification to buffer environmental variability and contribute to production stability. These findings are consistent with current approaches promoting biodiversity-based solutions to improve the resilience of agroecosystems under climate change.

Redesigning grasslands management through advances in Earth Observation, Artificial Intelligence, and Biophysical Modelling

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Session: 1. EFFICIENZA

Presentation: Poster

Although permanent grasslands are an important component of European agriculture, digital grassland management systems have not experienced advances comparable to those observed in arable systems. This gap reflects both the perception of grasslands as marginal systems and their ecological heterogeneity and management complexity, which have limited the applicability of EO and modelling tools. Recent advances in digital agriculture technologies are beginning to overcome these limitations. New EO missions provide higher spatial, temporal, and spectral resolution data; digital applications facilitate systematic field data collection; Artificial Intelligence (AI), combined with biophysical modelling, enhances data integration and analytics. Concurrently, increasing recognition of grasslands within climate adaptation and mitigation strategies and carbon farming initiatives is driving research investment and creating new opportunities for innovation. Within the AS τ ER Laboratory, we explore emerging digital agriculture technologies for sustainable grassland management. As illustrative examples of our agenda, we present findings from two recent European studies: Characterizing the spatio-temporal variability of grassland biomass and nutritional quality is critical for adaptive grazing management. However, state-of-the-art satellite-based approaches remain limited in their ability to retrieve forage quality indicators. In a case study in the Italian Alps, machine learning models were calibrated using 250 vegetation samples and field spectra collected in 2024 and 2025 from semi-natural grasslands in Valtournenche (Aosta Valley, Italy) and Val Camonica (Brescia, Italy). Maps of biomass and forage quality indicators, including protein and fiber content, were derived from PRISMA hyperspectral imagery (30 m spatial resolution) and validated against field measurements, achieving good predictive performance (LAI: $R^2 = 0.71$; biomass: $R^2 = 0.67$; dry matter: $R^2 = 0.65$; crude protein: $R^2 = 0.58$; ADF: $R^2 = 0.45$; NDF: $R^2 = 0.50$). These products enabled the spatial estimation of pasture metabolizable energy, providing valuable information to guide rotational grazing. Mowing frequency is a key indicator of grassland management intensity and productivity. However, operational frameworks for mapping mowing frequency at regional scales remain limited. We developed an automated remote sensing framework to monitor grassland mowing across Denmark (2017–2023) at 30 m spatial resolution. A Random Forest classifier was trained on field-level mowing records collected across multiple regions and years ($n = 497$), using 64-dimensional AlphaEarth satellite embeddings derived from an AI-driven EO foundation model as input features. The model achieved an accuracy of 78.2% while requiring six minutes to generate parcel-level predictions across Denmark. Once calibrated, the framework generates annual mowing

frequency maps, providing ready-to-use information for grassland monitoring. These results highlight the potential of EO, machine learning, and AI technologies to deliver scalable solutions for adaptive grassland management, monitoring, and decision-making.

Salinity Stress as an Elicitor of Bioactive Compound Accumulation in Cultivated Cardoon Seedlings

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Abstract ID: 281

Session: 1. EFFICIENZA

Presentation: Poster

Cultivated cardoon (CC) is a cross-pollinated species native to the Mediterranean Basin belonging to the Asteraceae family. It is closely related to globe artichoke [*C. cardunculus* L. var. *scolymus* (L.) Fiori] and wild cardoon [*C. cardunculus* L. var. *sylvestris* (Lamk.) Fiori], the latter being the progenitor of both cultivated forms. CC has long been used in folk medicine as a source of bioactive compounds, including phenolic compounds and sesquiterpene lactones. Previous studies have demonstrated that leaf extracts exhibit a wide range of biological activities, particularly antioxidant and anti-inflammatory properties. Since the biosynthesis and accumulation of these compounds are strongly influenced by environmental conditions, the application of elicitors under controlled growing conditions represents a promising strategy for obtaining CC seedlings enriched in bioactive compounds. In this view, this research, funded by the University of Catania within the framework of the “Piano di InCentivi per la Ricerca di Ateneo 2024/2026 (PIACERI)” project ALBION, aimed to evaluate salinity stress as an elicitor to obtain CC seedlings enriched in bioactive compounds under controlled conditions. ‘Altilis 41’, a CC line selected within a breeding programme for high biomass productivity and elevated content of bioactive compounds, was used in this study. Seeds were sown in plastic pots (10 cm diameter, 8 cm height), filled with a peat-sand mixture (40:60, v/v). Pots were maintained in a growth chamber under controlled conditions (18±1 °C; 13-h light/11-h dark photoperiod) and irrigated with deionised water ($EC \leq 0.01$ dS m⁻¹) until seedling emergence. From emergence to the fifth visible leaf stage, salinity treatments were imposed according to a 3 × 3 factorial design, combining three salt types (NaCl, KCl, CaCl₂) and three salinity levels (0, mild and severe), with three replicates per treatment. At harvest, seedlings were weighed, freeze-dried, and finely ground at room temperature. The resulting powder was stored at -20 °C until high-performance liquid chromatography (HPLC) analysis, which allowed the identification and quantification of bioactive compounds, primarily caffeoylquinic acids and flavones. The findings indicated that salinity-induced elicitation can promote the biosynthesis and accumulation of bioactive compounds in cultivated cardoon seedlings, highlighting the importance of optimising salt type and concentration to maximise bioactive compound accumulation while preserving plant growth.

Effect of seed treatment with biostimulants on tillering ability and root growth of different durum wheat genotypes

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Abstract ID: 289

Session: 1. EFFICIENZA

Presentation: Poster

Durum wheat (*Triticum turgidum* L. subsp. durum (Desf.) Husn.) is a strategic commodity for the Mediterranean countries. Frequently, durum productivity is threatened by climate change and the high year to year variability of weather conditions, which is typical of Mediterranean climate. In this context, studies that aim to increase the abiotic stresses resilience of the crop are crucial to safeguarding the future food security in that geographic area. Besides other factors, the ability of durum wheat to tolerate drought and heat stress during spring depends on morphological and physiological traits the plants developed in early growth stages (up to tillering). The aim of this study was to evaluate the effects of the application of a biostimulant on the morphological and physiological characteristics of several durum wheat genotypes during the tillering phase. An experimental biostimulant, consisting of extracts from the seaweed *Codium fragile* (Suringar) Hariot and the plant Indian fig opuntia (*Opuntia ficus-indica* (L.) Mill.) as well as plant growth promoting bacteria, was applied as seed dressing treatment. Two innovative durum wheat-*Thinopyrum* spp. recombinant lines (R5+ and R69-9/R5+), bearing genes of interest, were compared with their respective non-carrier lines (R5-, R69-9/R5-) and with the control cultivar 'Iride', under controlled growth conditions. An experimental factorial design with four replicates was applied to test the effect of biostimulant, genotype and their interaction on durum wheat response. The following plant traits were detected: number of leaves and tillers per plant, chlorophyll content (spad determination), final fresh and dry weight of shoot biomass, final root length and dry weight (BBCH-29). The results showed a significant effect of biostimulant and genotype on shoot and root system growth. The biostimulant treatment enhanced the number of culms per plant by 29%, while the root length increased by 28% compared with the untreated control. Genotype strongly influenced shoot system, especially in terms of number of culms and dry weight. The experimental lines R69-9/R5+ and R5+ produced more than 3 culms per plant, while the commercial cultivar Iride developed 2.4 culms per plant. R69-9/R5+ and R5+ showed also a longer root system when compared with their control lines (approx. 600 cm vs. 450 cm). Further studies are needed to extend this experiment over the tillering stage and under field conditions.

Biostimulants and Eco-Friendly Extraction Technologies Enhance Biomass and Essential Oil Production in *Salvia rosmarinus* L.

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Abstract ID: 301

Session: 1. EFFICIENZA

Presentation: Poster

Background. Medicinal and aromatic plants play a strategic role in Mediterranean farming systems because of their economic value and multifunctional uses, particularly for the production of essential oils and high-value secondary metabolites. Increasing climate variability requires agronomic strategies aimed at improving resource-use efficiency and crop productivity. In this context, biostimulants represent promising tools for enhancing crop performance in accordance with sustainability principles and the objectives of the European Green Deal. Likewise, eco-friendly extraction technologies may improve extraction efficiency while reducing environmental impacts. For *Salvia rosmarinus* L., improving biomass production and extraction efficiency is therefore of considerable practical relevance. **Objective.** This study evaluated the effects of different biostimulants on biomass production and essential oil yield of *S. rosmarinus* cultivated under Mediterranean field conditions and compared conventional and innovative extraction techniques in terms of efficiency and sustainability. The experiment was conducted under field conditions at the organic farm Sandemetrio s.r.l. (Specchia, southern Italy) on sandy-clay-loam soil. The experimental design was a randomized complete block with three replicates. Rosemary plants, obtained from cuttings of a commercial selection developed by PrimaVita, were transplanted in March 2024 on biodegradable mulched raised beds arranged in twin rows (0.90 × 1.80 m). Treatments included arbuscular mycorrhizal fungi (*Rhizophagus intraradices*), microalgae extracts, *Ascophyllum nodosum* extracts, chitosan hydrochloride formulations and an untreated control. Foliar applications were performed through two cycles: four applications during vegetative regrowth and three after the first harvest. Biomass was harvested mechanically by cutting plants at 15 cm above ground level. Dry biomass and essential oil yield (% w/w) were determined at two annual harvests. Essential oil extraction was performed by Clevenger hydrodistillation, steam distillation and microwave-assisted hydrodistillation (MAHD). Biostimulant application significantly affected biomass production and essential oil yield. Microalgae extracts produced the highest dry biomass yield, exceeding 8.0 t ha⁻¹ at the first harvest. At the second harvest, all treatments maintained a productive advantage over the untreated control. Essential oil yield reached approximately 0.75% (w/w) in microalgae-treated plants and 0.65% (w/w) in chitosan-treated plants, compared with about 0.40% in the control. MAHD provided essential oil yields comparable to conventional extraction methods while reducing extraction time from 2.5 h to approximately 30 min. These findings highlight the potential of integrating biostimulants and eco-friendly extraction technologies to improve productivity and sustainability of rosemary cultivation. Microalgae extracts proved to be the most effective treatment

for enhancing biomass and essential oil production in *S. rosmarinus*. Moreover, MAHD reduced extraction time and energy requirements while maintaining extraction efficiency. The integration of biostimulants and innovative extraction technologies represents a promising strategy for improving the sustainability of rosemary essential oil production under Mediterranean conditions.

Biostimulation Strategies and Sustainable Extraction Technologies for Biomass and Essential Oil Production in *Thymus vulgaris* L.

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Abstract ID: 302

Session: 1. EFFICIENZA

Presentation: Poster

Background. The cultivation of medicinal and aromatic plants is often constrained by the limited availability of authorized products for crop nutrition and protection. This limitation, exacerbated by climate change and the progressive reduction of chemical inputs, requires sustainable strategies capable of preserving both productivity and product quality. In this context, biostimulants represent valuable tools to improve plant physiological efficiency and enhance tolerance to environmental stresses. Moreover, the adoption of innovative and eco-friendly extraction technologies can increase the efficiency of essential oil extraction processes, contributing to the overall sustainability of the production chain. **Objective.** This study evaluated the effects of microbial and non-microbial biostimulants on biomass production and essential oil yield of *Thymus vulgaris* L. var. Varico 3 cultivated under Mediterranean field conditions and compared conventional and innovative extraction techniques. The experiment was conducted at the organic farm Sandemetrio s.r.l. (Specchia, southern Italy) under warm-arid Mediterranean conditions on sandy-clay-loam soil. Plants of *T. vulgaris* var. Varico 3 (Agroscope Changins-Wädenswil, Switzerland) were transplanted in March 2024 on biodegradable mulched raised beds arranged in twin rows (0.35 × 1.80 m) under localized micro-irrigation. The experimental design was a randomized complete block with three replicates. Treatments included arbuscular mycorrhizal fungi (*Rhizophagus intraradices*; 30 g plant⁻¹ at transplanting), microalgae extracts (2 L ha⁻¹ before flowering and 1 L ha⁻¹ after harvest), *Ascomyces nodosum* extracts (2.5 L ha⁻¹) and chitosan hydrochloride formulations (4.5 L ha⁻¹), compared with an untreated control. Four applications were performed from April to June and three after the first harvest. Biomass was harvested mechanically by cutting plants 15 cm above ground level. Dry biomass production at the first and second harvests and essential oil yield were determined. Essential oil extraction was performed by Clevenger hydrodistillation, steam distillation and microwave-assisted extraction. Biostimulant treatments significantly increased biomass production compared with the control. At the first harvest, microalgae extracts produced more than 7 t ha⁻¹ of dry biomass, whereas the control yielded approximately 4 t ha⁻¹. Mycorrhizae and chitosan treatments showed intermediate values ranging from 5 to 7 t ha⁻¹. At the second harvest, productivity decreased in all treatments, although microalgae maintained yields above 5 t ha⁻¹, whereas control and chitosan treatments dropped below 2 t ha⁻¹. Microalgae-treated plants also provided the highest essential oil yield, reaching 1.6–1.7% (w/w). Hydrodistillation achieved a maximum oil yield of 1.64% (w/w) after more than 2 h, whereas microwave-assisted extraction provided comparable yields while reducing processing time by 40–50%. Microalgae extracts proved

to be the most effective treatment for increasing biomass production and maintaining crop productivity after harvest. Microwave-assisted extraction reduced processing time and energy requirements without affecting essential oil yield. The combined use of biostimulants and innovative extraction technologies represents a promising strategy for improving the sustainability of medicinal plant production systems.

Greenhouse gas emission of Mediterranean rainfed cropping systems under different fertilization managements

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Abstract ID: 303

Session: 1. EFFICIENZA

Presentation: Poster

Agricultural soils represent a major source and sink of greenhouse gases (GHGs), and their management plays a critical role in determining the environmental sustainability of cropping systems. This study aims to evaluate the effects of soil tillage, fertilization strategies, and crop rotation on greenhouse gas emissions at the soil-atmosphere interface in a Mediterranean agroecosystem. The experiment was established at the Experimental Farm of the University of Catania, Italy (37°24' N, 15°03' E; 10 m a.s.l.), within a representative cereal-growing area characterized by a subtropical Mediterranean climate and a Xerofluvents soil with predominantly clayey texture. The research focuses on durum wheat (*Triticum turgidum* subsp. *durum*, cv. Mongibello) and selected rotational crops, including faba bean (*Vicia faba*), safflower (*Carthamus tinctorius*), crambe (*Crambe abyssinica*), and cardoon (*Cynara cardunculus*). The primary objective is to quantify soil emissions of carbon dioxide (CO₂), nitrous oxide (N₂O), methane (CH₄) and ammonia (NH₃) under contrasting tillage and fertilization practices, while assessing the influence of crop type and crop rotation on gas flux dynamics. The trial adopts a factorial experimental design comparing conventional tillage and no-tillage systems, three fertilization regimes, and different crop sequences. Fertilization treatments include: (i) mineral fertilization with 400 kg ha⁻¹ of NPK (20-10-10), (ii) organic fertilization with 3,200 kg ha⁻¹ of composted animal and plant residues (2.5-2-2.5), and (iii) an unfertilized control. Conventional tillage consists of disk harrowing before sowing, whereas the no-tillage treatment relies on weed mowing prior to sowing. Crops were established in November 2025. Greenhouse gas emissions are monitored continuously using a photoacoustic gas monitoring system composed of an Innova 1512 gas analyzer coupled with a static flow chamber installed in the field. This system enables high-frequency measurements of gas exchanges at the soil surface and provides detailed temporal information on emission patterns under different management conditions. In addition to soil GHG monitoring, plant physiological responses are assessed every two weeks from spring shoot emergence to autumn leaf senescence. Leaf gas exchange measurements are conducted on fully expanded upper leaves using an LCI-SD Portable Photosynthesis System, allowing the determination of net photosynthesis, transpiration, and stomatal conductance, together with measurements of photosynthetically active radiation, leaf

temperature, and air temperature. Expected outcomes include the identification of management combinations capable of mitigating GHG emissions while enhancing soil organic carbon storage, water-use efficiency, and overall agroecosystem sustainability. The results will contribute to the development of climate-smart agricultural practices tailored to Mediterranean cereal production systems and will support strategies aimed at reducing the environmental footprint of arable farming under current and future climatic conditions.

Assessing crop water use of industrial crops under different irrigation input using a Sub Water Retention System

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Abstract ID: 304

Session: 1. EFFICIENZA

Presentation: Poster

Water scarcity and low soil water retention capacity are among the main constraints affecting agricultural productivity in Mediterranean environments, particularly in sandy soils characterized by rapid drainage and limited water availability for crops. This study aims to evaluate the effectiveness of a Sub Water Retention System (SWRS) in improving soil water availability and crop performance in warm-season crops cultivated under contrasting irrigation regimes. In addition, the study seeks to develop and optimize a crop water-use model capable of predicting crop water use (CWU) and available soil water content (ASWC) using leaf area index (LAI) and soil moisture data as key inputs. The experiment was established by the University of Catania in southeastern Sicily on a sandy soil characterized by poor water retention capacity. The trial evaluates the response of three crops of increasing interest for biomass and industrial applications: castor bean (*Ricinus communis* L., cv. C1012), sweet sorghum (*Sorghum bicolor* (L.) Moench, cv. Sweet Betty), and hemp (*Cannabis sativa* L., cv. Futura 83). The SWRS consists of impermeable plastic strips 1.2 m wide and spaced 9 m apart, installed at a depth of 1 m below ground level in April 2023. The trial follows a split-plot experimental design, with irrigation regime as the main factor and crop species as the subplot factor. Three irrigation levels are compared: rainfed conditions (0% ET_m restoration), deficit irrigation (50% ET_m restoration), and full irrigation (100% ET_m restoration). Irrigation water is supplied through a drip irrigation system, and daily maximum crop evapotranspiration (ET_m) is estimated as the product of reference evapotranspiration (ET₀) and crop coefficients (K_c) according to the FAO methodology. A comprehensive monitoring program was implemented to assess crop growth, water dynamics, and system performance. Soil water content was measured every ten days at depths of 30 and 60 cm and at distances of 0, 1.5, and 4.5 m from the SWRS strips using dielectric soil moisture sensors (Teros 10, Meter). Canopy development was monitored monthly through measurements of leaf area index using an AccuPAR LP-80 ceptometer, while spatial variability was assessed through monthly drone surveys used to calculate the Normalized Difference Vegetation Index (NDVI). At crop maturity, total aboveground biomass and seed yield were determined from replicated sampling plots located at different distances from the SWRS strips. Crop water balance was evaluated using both measured soil moisture trends and a process-based crop water model. The model estimates daily

crop water use as a function of ET_0 , crop-specific coefficients derived from LAI, and a stress index related to soil water availability. Available soil water content is dynamically simulated through daily water balance calculations accounting for rainfall, irrigation inputs, and crop water consumption. Model parameters controlling the relationships between LAI, crop coefficients, and water stress were optimized using the Nelder–Mead simplex algorithm by minimizing the mean squared error between predicted and observed soil water content. The study will provide valuable information on the capacity of SWRS technology to enhance water conservation, improve crop productivity, and increase resilience to drought in sandy Mediterranean soils.

Evaluation of local forage legumes and grasses under Sicilian Mediterranean conditions

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Abstract ID: 305

Session: 1. EFFICIENZA

Presentation: Poster

In recent years, Mediterranean agroecosystems are shaped by significant seasonal variability, with mild and wet winters followed by hot, dry summers. Changes in precipitation patterns, together with rising temperatures and increasing atmospheric CO₂ concentrations, have significantly affected forage crops, altering their nutritional value and ultimately influencing animal performance. These challenging climatic conditions highlight the importance of promoting local ecotypes, which ensure the availability of resilient Mediterranean species capable of resist environmental stress. Local ecotypes in Mediterranean regions are persistent and well adapted, capable of maintaining satisfactory agronomic performance under drought conditions. The aim of this study was to evaluate the adaptability of self-reseeding legume species from the genera *Trifolium* and *Medicago*, together with local forage ecotypes, including both grasses and legumes, to Mediterranean environmental conditions. The research focused on assessing their productive performance in terms of biomass yield and forage quality characteristics. The field trial was conducted during the 2024/2025 growing season in Villarosa, in the province of Enna (37°36' N, 14°11' E; 650 m a.s.l.), a site representative of the inland Sicilian hilly environment characterized by a semi-arid Mediterranean climate. Thirteen annual and perennial species, each with different varieties, were cultivated. The experimental design consisted of randomized blocks with three replicates, with individual plot size of 14 m² (2 × 7 m). Sowing was carried out in November 2024. Throughout the trial, temperature and rainfall data were recorded. Herbage samples were collected from a representative area of each plot at different times from March to June for forage quality assessment. Considering the dry biomass production, species such as *Lolium multiflorum*, *Hedysarum coronarium*, and *Vicia faba* var. *minor* demonstrated the highest productivity under Mediterranean semi-arid conditions, confirming their suitability for these environments. Crude protein content showed a clear decline across all species as plant maturity progressed. In grass species, crude protein levels decreased markedly, reaching final values of approximately 6% at full maturity. In contrast, legume species maintained higher protein concentrations throughout the season, with final values generally remaining above 10%, reflecting their intrinsically greater nitrogen content and slower decline relative to grasses. These patterns align with the typical dynamics of forage maturation in Mediterranean systems. Overall, these results

emphasize the importance of strategic harvest timing and appropriate species selection to optimize livestock performance. For sustainable and productive livestock farming in Mediterranean environments, the findings support the use of cereal–legume mixtures, either through intercropping or rotation, as an efficient strategy to enhance forage availability and quality.

Biostimulant strategies to enhance functional metabolite production in aromatic Lamiaceae for nanosponge-enabled active packaging

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Abstract ID: 309

Session: 1. EFFICIENZA

Presentation: Poster

The growing demand for active packaging systems is promoting the use of plant-derived compounds with antimicrobial and antioxidant activity. Aromatic species belonging to the Lamiaceae family are valuable sources of essential oils and phenolic compounds, but their industrial exploitation is limited by variability in biomass and metabolite production, as well as by the volatility and chemical instability of their active molecules. Encapsulation into nanosponges may improve their protection, controlled release and compatibility with packaging matrices. However, this downstream application requires standardized plant material obtained through reproducible agronomic protocols. This study developed an integrated methodological approach for the cultivation and phenotyping of aromatic Lamiaceae aimed at producing biomass suitable for the extraction of functional compounds intended for nanosponge-enabled active packaging. A preliminary controlled-environment experiment was performed on *Lavandula* spp., *Origanum majorana*, *Mentha* spp., *Origanum vulgare*, *Rosmarinus officinalis*, *Salvia officinalis* and *Thymus vulgaris*. Species-specific cultivation protocols were developed, moderate salinity was evaluated as a potential elicitor, and scanning electron microscopy was used to standardize the observation of glandular trichomes and other leaf secretory structures associated with essential oil biosynthesis. Five species were subsequently selected for testing the effect of two commercial biostimulants on plant development and the concentration of functional molecules: *Mentha* spp., *S. officinalis*, *O. vulgare*, *T. vulgaris* and *O. majorana*. Plants were clonally propagated from mother plants. Cuttings were rooted in cell trays filled with a commercial growing medium and vermiculite mixture and maintained in a floating system. After rooting, plants were transferred to the aeroponic system and subjected to foliar applications of two biostimulants, one containing seaweed extracts and the other amino acids, along with an untreated control. Plant responses were assessed at final harvest through biometric measurements related to biomass production, leaf development, dry-matter accumulation and biomass partitioning. Preliminary analyses revealed marked differences among species and formulations. The seaweed-extract biostimulant generally produced the most favorable effects on shoot growth and leaf development, whereas the amino acid formulation resulted in more variable responses. Depending on the plant species and product, treatments positively, negatively or only marginally affected biomass accumulation, leaf expansion and biomass allocation. These findings indicate that biostimulant effects in aromatic plants cannot be generalized and are strongly influenced by the interaction

between plant species and formulation type. The proposed approach provides an agronomic screening framework for identifying suitable species -biostimulant combinations and improving the production of plant biomass intended as a source of functional metabolites. The integration of biometric and morpho-anatomical data with phytochemical analyses will establish whether the observed growth responses correspond to increased yields of antimicrobial and antioxidant compounds for subsequent encapsulation into nanosponges and incorporation into active packaging materials.

Integrating Sentinel-2 Vegetation Indices and Field Measurements for Estimating Pasture Nitrogen Content

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Abstract ID: 311

Session: 1. EFFICIENZA

Presentation: Poster

Accurate monitoring of pasture nitrogen status is crucial for enhancing nutrient management and serves as the basis for real-time detection of forage quality. The present study evaluated the preliminary workflow integrating field measurements and Sentinel-2 vegetation indices to estimate canopy nitrogen content across seven farms. In the context of the MONALISA (<https://monalisa4land.eu/>), which aims to implement innovative practices to restore and prevent land degradation, ground measurements (aboveground biomass and nitrogen concentration) were carried out across farms at 74 sampling points. The range of dry aboveground biomass measured was from 196.6 to 8175.6 kg ha⁻¹, while the range of plant nitrogen concentration was from 0.90% to 4.38%. The Canopy Nitrogen Index (CNI) was calculated by positioning observed nitrogen concentration between biomass-dependent upper and lower nitrogen boundary curves. The Sentinel-2 Canopy Chlorophyll Content Index (CCCI) was derived from the Normalised Difference Vegetation Index (NDVI) and the Red-Edge NDRE using NDVI-dependent upper and lower NDRE boundaries. The nitrogen content predicted by combining CCCI-derived nitrogen concentration with measured biomass exhibited a strong correlation with observed nitrogen content (p-value < 0.001; R² = 0.747). The prediction residuals were found to be 13.63 kg ha⁻¹ of N for RMSE and 8.04 kg ha⁻¹ of N for MAE. However, a calibration slope of 0.553 indicated compression of the prediction range, with overestimation at low nitrogen levels and underestimation at high levels. These preliminary findings demonstrate the potential to estimate pasture nitrogen content from combined field and Sentinel-2 data, while highlighting the need for stronger calibration and independent validation. Subsequent research endeavors will entail developing Sentinel-2 and machine-learning models to predict dry biomass to produce a fully remote-sensing-based assessment of pasture nitrogen content at farm scale, supporting more spatially targeted grazing and nutrient-management decisions.

Session: 2. SOSTITUZIONE

Integrating Phosphate-Solubilizing *Bacillus* Consortia into Durum Wheat Fertilization: Impact on Soil P Dynamics, Canopy Physiology and Yield

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Abstract ID: 161

Session: 2. SOSTITUZIONE

Presentation: Oral

In the context of Mediterranean agro-ecosystems, the optimization of nutrient use efficiency represents a critical challenge for sustainable durum wheat (*Triticum durum* Desf.) production. In these regions, alkaline and clay-rich soils significantly limit the bio-availability of phosphorus (P), often constraining canopy development and final grain yield. Consequently, reducing synthetic fertilizer inputs while maintaining competitive crop performance requires innovative biotechnological interventions. This study investigates the agronomic potential of a multi-strain *Bacillus* consortium as a strategic bio-inoculant to modulate phosphorus dynamics and enhance crop physiological status under varying fertilization regimes. Field experiments were conducted during the 2023/24 growing seasons at two contrasting Sicilian locations: Campo Carboj and Sparacia. These sites were selected for their divergent edaphic characteristics, with Sparacia being particularly characterized by clay-rich soils with high P-immobilization capacity. The experimental layout followed a randomized complete block design (RCBD) with three replicates. A comprehensive set of eight treatments (S0–S7) was evaluated, encompassing diverse application modalities: seed coating, soil spraying at three distinct rates, and integrated seed plus soil applications. The research adopted a multi-level monitoring approach. Soil available P (P205) was quantified post-harvest to assess the solubilizing efficiency of the consortium. Simultaneously, the physiological response of the crop was monitored across key phenological BBCH stages using high-precision indicators of canopy function, including the SPAD chlorophyll index, stomatal conductance (Gs), and the Normalized Difference Vegetation Index (NDVI) to track vigor and photosynthetic efficiency. The results demonstrated that microbial inoculation significantly altered soil-plant P dynamics. The most pronounced effects were observed at the Sparacia site, where the *Bacillus* consortium successfully mitigated the limitations of P-immobilizing soils. In these conditions, microbial treatments achieved soil P availability levels comparable to those obtained through conventional mineral fertilization. Furthermore, the bio-inoculants induced a robust physiological enhancement; unfertilized plots treated with the consortium exhibited a substantial increase in plant height (up to +23%) and sustained superior SPAD and NDVI values from tillering through grain filling. Interestingly, the study revealed a site-specific divergence between physiological vigor and reproductive output. While the physiological boost was more evident in the clay-rich soils of Sparacia, the highest yield increases were recorded at Campo Carboj, particularly under the combined seed and soil application protocols (S5, S6, and S7). These findings suggest that multi-modal inoculation strategies provide the most consistent

agronomic benefits. In conclusion, the *Bacillus* consortium proved to be an effective tool for partially offsetting mineral fertilizer reductions, sustaining both the physiological health and the productive performance of durum wheat through enhanced soil P mobilization, with efficacy closely mediated by local edaphic contexts.

A Farmer-Oriented Decision Support System for Site-Specific Weed Management in Maize

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Abstract ID: 211

Session: 2. SOSTITUZIONE

Presentation: Oral

The transition towards more sustainable cropping systems requires substantial reductions in herbicide use without compromising crop productivity. Although site-specific weed management (SSWM) is widely recognised as a promising approach, its adoption remains limited due to technical complexity, cost, and limited transferability of existing solutions. To address these barriers, we developed SWIM (Smart Weed Impact Management), a user-oriented decision support system that transforms low-cost UAV-RGB imagery into operational herbicide prescription maps for maize fields. Unlike most image-based approaches focused solely on weed mapping, SWIM directly links weed infestation to expected yield loss and economic intervention thresholds, enabling management decisions based on agronomic and economic criteria. SWIM integrates three sequential modules: (i) weed detection, (ii) estimation of yield loss due to weed competition, and (iii) generation of prescription maps for Patch Spraying and Variable Rate Application (PSA and VRA). The system is implemented in two versions: a Simple Method (SM), based on minimal user expertise and rapid site-specific calibration, and an Improved Method (IM), which requires the evaluation of spatial crop density and a more extensive calibration activity to improve accuracy. SWIM was tested in a maize field located in Central Italy using UAV-acquired RGB imagery. Weed green cover was estimated through a simple image-based approach in which maize green cover was subtracted from total green cover derived from aerial images, providing a low-cost alternative to more complex weed-recognition techniques. The resulting weed green cover estimates were subsequently used to quantify competitive pressure and identify economically justified intervention thresholds. Both methods showed strong performance in weed detection, with root mean square errors (RMSE) below 0.10 and concordance correlation coefficients (CCC) exceeding 0.91. However, the IM more effectively captured within-field spatial variability and provided more robust estimation of the economic intervention thresholds. Consequently, the resulting prescription maps identified substantial opportunities for reducing herbicide applications, with estimated savings of 44% (for SM) and 28% (for IM) compared with conventional uniform application. Beyond its technical performance, SWIM introduces a practical framework that actively involves farmers in defining acceptable economic risk levels while avoiding dependence on expensive sensors, proprietary

software, or advanced artificial intelligence models. This combination of accessibility, transparency, and agronomic relevance makes the system particularly suitable for supporting the broader adoption of precision agriculture in real farming conditions. The proposed DSS provides a practical framework for improving herbicide-use efficiency through SSWM while maintaining a strong focus on operational feasibility. By combining low-cost sensing technologies with economically based decision rules, SWIM may contribute to the wider adoption of precision weed management in maize production systems. In addition, its farmer-oriented design can help bridge the gap between digital innovation and practical field management, promoting a more effective integration of precision agriculture technologies into routine farming decisions.

Novel smart fertilizers for a sustainable management of fertilization on common wheat and maize

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Abstract ID: 212

Session: 2. SOSTITUZIONE

Presentation: Oral

Excessive nitrogen (N) inputs in agriculture have markedly increased N losses resulting in considerable environmental concerns. Reducing these losses without compromising yields remains a pressing challenge for agriculture. Among the proposed strategies, smart stabilized fertilizers (SSFs) have attracted growing interest due to their potential to improve N use. We investigated the impact of two novel SSFs formulations on wheat and maize. These fertilizers were based on urea coated with methylene blue (BM) and a gallic acid (GA), and their effectiveness was compared with that of urea and a commercial urease inhibitor (NBPT). Field trials were carried out on common wheat and maize in Italy across two cropping seasons (2023–2024 and 2024–2025). All treatments received a uniform N rate of 150 and 200 kg N ha⁻¹ for wheat and maize, respectively. Urea was applied in split applications: wheat received 20% of total N at sowing, 40% at topdressing, and 40% at flowering and maize received 25% of total N at sowing and 75% at tillering. Conversely SSFs were applied as a single dose at sowing. Crop vigor was evaluated using NDVI on wheat. The effectiveness of SSFs was assessed by analyzing yields and grain quality. On wheat, the trend of the NDVI demonstrated the effectiveness of SSFs in both growing seasons, performing comparably to NBPT and urea. During the first season, grain yields were comparable to those of NBPT and urea, averaging 7.6 t ha⁻¹. In the second season, the novel SSFs resulted in grain yields comparable to NBPT (averaging 6.6 t ha⁻¹) but lower than urea (9.6 t ha⁻¹). Straw yield followed a similar trend. The two-year cumulative yield analysis confirmed that urea had a greater effect on grain production, whereas no significant differences were observed regarding straw yield. Grain protein content analysis revealed that the performance of SSFs was similar to that of NBPT but lower than that of urea in both years, partially confirming the observations made for crop yields. On maize, during the first growing season, BM showed grain yields similar to those of NBPT and urea (average 8.8 t ha⁻¹), whereas the yields obtained from GA were lower and comparable to the control (average 5.6 t ha⁻¹). In the second season, both SSFs achieved grain yields similar to NBPT and urea (average 7.3 t ha⁻¹). However, the combined two-year data analysis revealed that grain yields for GA remained comparable to the control and lower than the other treatments. Conversely, biomass production exhibited yields from

SSFs similar to NBPT and urea (average 9.1 t ha^{-1}). The effectiveness of both SSFs was further confirmed by the analysis of grain protein content, which showed comparable performance to NBPT and urea with an average value of 9.7%. Results from this study suggest that a single basal application at sowing offers interesting applications to support wheat and maize yields. However, further studies should better clarify the fertilization potential of tested SSFs.

UAV-based machine learning reveals climate-dependent effects of cover crops and nitrogen source on silage maize ecophysiology

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Session: 2. SOSTITUZIONE

Presentation: Oral

Optimizing nitrogen (N) management in intensive silage maize systems is crucial for maximizing crop productivity while reducing environmental impacts. The transition towards integrated conservation practices, such as combining cover crops (CCs) and livestock slurry, can mitigate the reliance on synthetic fertilizers. However, organic matrices involve nutrient release dynamics that differ from those of mineral N sources, potentially affecting maize physiological responses and final performance. Since traditional ground-based surveys are labor-intensive and lack temporal responsiveness, this study evaluated the potential of unmanned aerial vehicle (UAV)-derived vegetation indices and machine learning (ML) algorithms to estimate maize physiological activity and determine how integrated management strategies influence crop functioning, yield, and silage quality. A two-year field trial was conducted in the Po Valley, northern Italy, under contrasting seasonal conditions: cumulative rainfall from CC sowing to maize harvest was 525 mm in 2023 and 1051 mm in 2024, with maximum temperatures reaching 38.6 °C and 39.4 °C, respectively. The experiment tested two N fertilization strategies, based on slurry or urea, combined with eight CC treatments, including single species, binary and ternary mixtures, and bare soil, within a split-plot design. UAV-based multispectral imagery was used to calculate 77 vegetation indices, which were coupled with ML models to estimate structural and physiological traits, including leaf area index (LAI), plant height, SPAD, linear electron flow (LEF), and photoprotective parameters such as NPQt, Φ_{NO} , and Φ_{NPQ} . A PCA-based Composite Index (PCI) was then developed to rank treatments by rewarding biomass production and forage digestibility while penalizing physiological stress. Non-linear ML models, particularly Random Forest and Support Vector Regression, outperformed linear approaches. They accurately estimated both structural traits, such as LAI ($R^2 = 0.90$) and plant height ($R^2 = 0.97$), and physiological traits, including SPAD ($R^2 = 0.97$), LEF ($R^2 = 0.78$), NPQt ($R^2 = 0.75$), and Φ_{NPQ} ($R^2 = 0.81$). Inter-annual climatic variability strongly reshaped treatment performance. In 2023, when rainfall was lower and seasonal conditions were comparatively more favorable, the best

holistic performance was achieved by urea combined with ryegrass ($PCI = 0.55$), whereas complex organic systems were penalized, likely due to temporary N immobilization. Conversely, in the wetter and thermally stressful 2024 season, slurry-based systems became highly competitive: slurry combined with ryegrass and the ternary ryegrass–mustard–vetch mixture reached PCI values of 0.73 and 0.71, respectively, while urea combined with complex mixtures ranked among the lowest-performing treatments ($PCI = 0.43$). Overall, UAV-based multispectral imagery coupled with ML provided a functional diagnostic platform for monitoring maize ecophysiology. The results show that the effectiveness of conservation agronomic practices is not static, but depends on the dynamic interaction between N source, CC complexity, and seasonal climatic forcing.

INTEGRATING COVER CROPS AND IN-PLANT BIOSENSING TO IMPROVE RESOURCE USE EFFICIENCY IN SILAGE MAIZE UNDER MEDITERRANEAN CONDITIONS

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Abstract ID: 173

Session: 2. SOSTITUZIONE

Presentation: Pitch

The transition toward climate-resilient cropping systems requires innovative agronomic strategies capable of improving resource use efficiency while reducing external inputs. In this context, cover cropping and digital plant monitoring technologies may contribute to the development of integrated management approaches for maize systems. A field experiment was conducted in 2025 growing season at the Fondazione per l'Agricoltura "F.lli Navarra" (Ferrara, Italy) to evaluate the effects of winter cover crops combined with reduced nitrogen fertilization on maize physiological performance, soil parameters, and biomass production. In parallel, wireless bioristor sensors were tested as a *in vivo* digital tool for real-time crop monitoring. The experimental design compared two soil management strategies: i) a conventional system with bare soil during winter and full nitrogen fertilization (Conv_N100), and ii) a cover crop system based on a mixture of hairy vetch (*Vicia villosa* Roth.) and black oat (*Avena strigosa* L.) terminated by roller crimping before maize direct seeding, combined with a 50% reduction in N fertilization (HV+BO_N50). Throughout the maize growing cycle, soil parameters and plant physiological traits were periodically monitored. Daily diurnal measurements were performed on 15 and 30 July 2025. Wireless bioristor nodes were installed inside maize stems to continuously monitor plant physiological responses and identify potential stress events. Results highlighted distinct responses between management systems. Seasonal monitoring showed that the HV+BO_N50 treatment improved late-season soil moisture retention compared with the conventional system, while soil temperature remained similar between treatments. Electrical conductivity dynamics differed markedly, suggesting modifications in nutrient availability and soil solution composition under cover crop management. From a physiological perspective, maize grown under conventional management exhibited consistently higher SPAD and NDRE values, reflecting greater nitrogen availability. However, NDVI values indicated comparable

canopy development and biomass establishment between treatments, with the cover crop system showing superior early vigor. Diurnal analyses revealed important differences in crop physiological behavior under high evaporative demand. On both monitoring dates, HV+BO_N50 plants maintained higher stomatal conductance and transpiration rates during critical daytime hours, suggesting improved hydraulic functionality and greater tolerance to transient stress conditions. Moreover, chlorophyll fluorescence measurements indicated higher photochemical efficiency during midday stress periods in the cover crop treatment, particularly on 15 July. Bioristor monitoring confirmed these trends, identifying shorter and less severe stress periods in HV+BO_N50 compared with Conv_N100. Bioristor sensor data also suggested that at least one irrigation event could potentially have been avoided without compromising crop physiological status, demonstrating the potential of in-plant sensing technologies to support precision irrigation management. At harvest, conventional management achieved the highest dry matter yield (17.96 t ha⁻¹), while HV+BO_N50 produced lower biomass (14.7 t ha⁻¹) but significantly taller plants. Overall, the integration of winter cover crops with reduced nitrogen fertilization improved maize physiological resilience and water-use dynamics, although with some yield penalty. The combined use of sustainable agronomic practices and wireless biosensing technologies represents a promising strategy to support the eco-digital transition of Mediterranean cropping systems.

Trade-offs between soil conservation and crop productivity under different tillage systems in Mediterranean durum wheat

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Session: 2. SOSTITUZIONE

Presentation: Pitch

Soil management is a key lever for climate-smart agriculture in Mediterranean environments, where water scarcity and organic matter depletion threaten long-term sustainability. Conventional tillage (CT) remains widespread but accelerates organic carbon losses and increases evapotranspiration, whereas minimum tillage (MT) and no-tillage (NT) are proposed to enhance soil health and water conservation. Trade-offs with productivity and nitrogen use efficiency (NUE) remain debated under rainfed conditions, where yield stability is a primary farmer concern. This study evaluates how CT, MT and NT affect soil carbon storage, water dynamics, nitrogen cycling and durum wheat productivity in the Capitanata plain (Southern Italy). Data were generated by the CARBOND platform (<https://app.carbond.eu/>), a process-based model integrating crop growth, soil carbon, water balance and nitrogen modules, cross-calibrated against a 16-year field experiment. One annual value per tillage system was available for 19 consecutive years (2004–2022). To account for the natural dependence among observations within the same year, years were treated as repeated temporal blocks. Global differences among tillage systems were tested with the Friedman test, pairwise comparisons with paired Wilcoxon signed-rank tests with Holm correction, and effect size quantified by Kendall's W. All indicators showed statistically significant tillage effects. Soil organic carbon (SOC; 0-0.6 m depth) responded strongly to reduced disturbance: NT stored the highest stock (78.9 t C ha⁻¹), followed by MT (78.3) and CT (76.3 t C ha⁻¹). All pairwise differences were significant and the near-perfect Kendall's W (1.00) indicates that NT and MT outperformed CT in every single year – a remarkably stable pattern. Grain yield followed the opposite hierarchy: CT produced the highest average yield (4.06 t ha⁻¹), significantly above MT (3.73) and NT (3.67 t ha⁻¹), which did not differ. Biomass showed the same ranking, confirming that conventional tillage favours above-ground productivity. Evapotranspiration was significantly higher under CT (397 mm) than under MT and NT (388 mm) – a modest but consistent reduction in water consumption, a valuable trait in rainfed Mediterranean agriculture. Both NUE and nitrogen uptake decreased progressively from CT to MT to NT, with all pairwise differences significant, likely reflecting greater soil mineralisation and root exploration under conventional tillage. Deep percolation showed a smaller, non-monotonic response

(Kendall's $W = 0.23$): MT was slightly higher than both CT and NT (Holm-corrected $p < 0.02$), while CT and NT did not differ – a real but minor influence on a flux largely driven by interannual climate variability. These findings highlight a clear trade-off: CT maximises yield and nitrogen efficiency but depletes soil organic carbon and increases water consumption, whereas NT and MT enhance carbon sequestration and reduce water losses at the cost of moderate yield penalties. Conservation agriculture is therefore supported in Mediterranean rainfed systems for soil and water sustainability, although closing the yield gap will require agronomic optimisation – integrated nutrient management or crop rotation strategies – to make these systems both environmentally and economically viable for farmers.

Nanotechnology, circular bioeconomy and Safe-and-Sustainable-by-Design approaches for next-generation nutrient management

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Session: 2. SOSTITUZIONE

Presentation: Pitch

Improving nutrient use efficiency (NUE) is one of the main challenges facing modern agriculture, particularly in relation to nitrogen (N) and phosphorus (P), whose low recovery efficiency in conventional fertilization systems contributes both to reduced agronomic performance and to significant environmental impacts. Nitrogen losses together with phosphorus immobilization and runoff, are among the major drivers of soil and water degradation, greenhouse gas emissions, and declining sustainability of intensive cropping systems. The development of nano-enabled fertilization strategies represents a promising approach to redesign nutrient delivery systems through the integration of controlled-release materials, rhizosphere microbiome interactions, and circular economy principles. Recent advances in nanotechnology are opening new opportunities for the development of fertilizers capable of improving nutrient synchronization with crop demand, enhancing nutrient bioavailability, and reducing nutrient dispersion in the agroecosystem. Nanoformulations may increase nutrient delivery by modulating release kinetics, improving root-soil interactions, and acting synergistically with plant growth-promoting microorganisms. These approaches are particularly relevant within the framework of precision agriculture and sustainable intensification, where improving NUE is a key target for both productivity and environmental protection. Within the framework of the 2022 MUR-PRIN project Cleopatra (2023–2026), coordinated by the University of Udine, this contribution presents an integrated research activity focused on the development of nano-hybrid fertilizers. The proposed strategy is based on nano-hydroxyapatite (nHAP) particles obtained from poultry bone waste and combined with phosphate-solubilizing bacteria, with the aim of improving phosphorus availability and reducing nutrient dispersion. Two waste-derived nHAP formulations were evaluated under both soil leaching conditions and semi-controlled crop experiments in comparison with conventional triple superphosphate (TSP). Results demonstrated that nano-hydroxyapatite formulations reduced phosphorus losses compared with conventional fertilization, while maintaining crop productivity and plant P nutrition at comparable levels. Moreover, specific formulations enhanced maize biomass accumulation and canopy vigor, indicating potential effects on crop physiological efficiency beyond simple nutrient supply. Although microbial inoculation did not significantly increase plant performance under the tested conditions, the integration of nanostructured fertilizers with beneficial microorganisms remains a promising route for rhizosphere engineering and nutrient mobilization

strategies. Building upon these preliminary findings, the recently approved Nano2U project, also coordinated by Udine, extends the nano-enabled fertilization approach to nitrogen management through the development of second-generation nanofertilizers designed according to Safe and Sustainable by Design principles. The project integrates bio-based nanocarriers derived from crustacean waste, controlled urea release systems, in vitro toxicological assessment, and field-scale agronomic evaluation on maize. Particular emphasis is given to combining agronomic efficiency with environmental and occupational safety, thereby addressing one of the main challenges currently limiting the large-scale adoption of nanotechnologies in agriculture. The integration of advanced phenotyping tools, nitrogen balance analyses, and NUE-related indices will further contribute to defining the potential role of engineered nanofertilizers. Overall, the presented research supports the potential of waste-derived nanofertilizers as multifunctional tools capable of combining nutrient efficiency, environmental protection, and valorization of agro-industrial residues. Nano-enabled fertilization may contribute to the transition toward more efficient and resilient cropping systems, acting as a technological interface between circular bioeconomy approaches, microbiome-assisted agriculture, precision nutrient management, and next-generation strategies for improving NUE.

Environmental influence on Plant Growth-Promoting Bacteria performance in relation to wheat productivity and soil microbiome dynamics

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Session: 2. SOSTITUZIONE

Presentation: Pitch

Plant growth-promoting bacteria (PGPB) are increasingly investigated as a sustainable strategy to enhance crop productivity and resilience under climate variability. However, the effectiveness of microbial inoculation is strongly influenced by environmental conditions, soil properties, and host genotype, particularly across contrasting agroecological environments. This study evaluated the response of bread and durum wheat to different PGPB inoculations under different pedo-climatic conditions in northern and southern Italy over three growing seasons. Furthermore, soil microbial biodiversity was characterized to investigate the relationship between environmental conditions and microbial community dynamics. Field experiments were conducted during three consecutive growing seasons (2022-2025) in Piedmont (Turin, northern Italy) and Apulia (Foggia, southern Italy). One bread wheat (cv. Solehio) and one durum wheat (cv. Fuego) genotypes were tested in both locations. Three commercial microbial inoculations (MI) were tested against an untreated control (CTR), including: MI1) a consortium of *Azospirillum brasilense* and *Pantoea foetida*, b) a consortium of *Azotobacter salinestris* and mycorrhizae (*Glomus* spp.), c) *Bacillus subtilis*. Microbial inoculation was carried out at top dressing in each experiment. Crop growth and productivity were assessed

through grain yield, grain protein content, and canopy development monitored by normalized difference vegetation index (NDVI) measurements from tillering to physiological maturity. Seasonal variability markedly affected crop performance at both locations, with precipitation distribution representing the major driver of yield response. Grain yield and its components were strongly influenced by soil water availability, particularly during stem elongation and grain filling. The effectiveness of PGPB inoculation differed according to environmental conditions, with the most consistent positive responses observed under the warmer southern Italian environment. Microbial community analysis revealed significant shifts in soil biodiversity associated with climatic conditions. The abundance of N-fixing bacteria and members of the Pseudomonadaceae family showed a strong dependence on soil water availability, suggesting a greater sensitivity of these microbial groups to drought stress. Conversely, Bacilli populations exhibited higher persistence under water-limited conditions, confirming their greater drought tolerance and ecological adaptability in semi-arid environments. Grain yield enhancement associated with microbial inoculation was generally greater in Foggia (from +6.7 to +13.3 %) than in Turin (from +3.4 to +6.8 %), possibly due to higher temperatures that may have promoted improved microbial survival. No significant effects of PGPB treatments were observed on grain protein content in both locations. NDVI monitoring effectively described crop growth dynamics throughout the growing cycle, and the area under the curve of canopy development was significantly correlated with grain yield across environments and seasons. These findings highlight the importance of integrating physiological and microbial indicators to better understand crop responses to biostimulant-based management strategies. Overall, the study demonstrates that the agronomic effectiveness of PGPB inoculation in wheat is highly environment-dependent and closely linked to climatic variability and soil microbial adaptation, with particularly promising results under Mediterranean conditions.

Residual effects of innovative solarization Solin ®, with or without adding of organic substances, on yield of cherry tomato treated with beneficial microorganism

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Session: 2. SOSTITUZIONE

Presentation: Pitch

Solarization is an established agricultural practice to reduce the load of pathogens into the soil, inactivate weed seeds, and control fungi and nematodes. Traditional practice consists of the use of plastic films but, recently, an innovative system has been put in place, based on the application to soil of a charcoal-based black liquid product. The Solin® was sprayed on the soil surface after pre-solarization irrigation, with the aim of creating a coating capable of increasing solar radiation absorption, while reducing the solarization duration (30-45 days). In the current study, we wanted to evaluate the residual effect of Solin® solarization treatments with or without adding of organic substances (digestate and vermicompost) on cherry tomato treated (1 or 2 application) or non with beneficial microorganisms (*Trichoderma harzianum*-T22 and *Clonostachys Rosea*-GNL). The Kimberlino tomato hybrid was transplanted after two lettuce cycles during spring 2025 (28 March), approximately 7 months after solarization, and harvested on (26 June). The experiment was carried out at the experimental site, Gussone Park, of the Department of Agricultural Sciences of Portici. The solarization treatments were: i) non-solarized control (NS); ii) Solin® Solarization (Sol); iii) Solin® Solarization + digestate (SolDig); iv) Solin® Solarization + vermicompost (SolVer). The microbial treatments were: i) non treated plants (NT); ii) plants treated with GNL (GNL); iii) plants treated with T22 (T22); iv) plants treated with GNL 2 applications (GNL+) v) plants treated with T22 2 applications (T22+). All treatments were replicated 3 times per a total of 60 plots (4 solarization x 5 beneficial microorganism application x 3 replicates). At the harvest, the marketable yield, number and mean weight of marketable fruits, as well as Total soluble solids (TSS, expressed as °Brix) and firmness were determined. Solarization treatments always elicited tomato marketable yield compared to NS (4,7 kg m⁻²), with the greatest increase in SolDig and SolVer (+ 23,4%). Similarly, the beneficial microorganism application boosted the marketable yield, that ranged between 4,7 of NT and 5,8 kg m⁻² of GNL. The GNL+ and T22+ treatments did not change the yield level. As for qualitative traits, SolVer and SolDig slightly improved the TSS: 7.35 and 7.34 compared to 7.21 and

7.13 of NS and Sol, respectively; instead, no effects were recorded for firmness, with 0.67 mean value. The application of beneficial microorganism did not affect TSS and firmness. In conclusion, solarization has a positive residual effect on tomato yield and quality (TSS), while the beneficial microorganism's application improves only marketable yield, irrespective of microorganism. However, further tests are needed to better investigate the crop response, especially for qualitative traits.

Regional-scale assessment of agri-environmental-climatic measures using an ensemble of agroecosystem models

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Session: 2. SOSTITUZIONE

Presentation: Pitch

Agri-environmental-climatic measures (AECMs) under the EU Common Agricultural Policy (CAP) are key instruments for reducing environmental impacts of agricultural systems. However, their effectiveness is highly dependent on local soil, climate, and management conditions, making regional-scale assessments essential to support evidence-based policy design. Process-based agroecosystem models integrated within Geographic Information Systems (GIS) provide a cost-effective framework for evaluating environmental outcomes across large and heterogeneous territories. Nevertheless, projections from individual models remain affected by structural uncertainty arising from differences in process representation. Model ensemble approaches can improve the robustness of assessments by combining complementary model structures and explicitly quantifying uncertainty. This study applied an ensemble of three process-based agroecosystem models—EPIC, DNDCv.CAN, and DayCent— within a GIS platform to evaluate selected AECMs included in the 2023–2027 CAP Strategic Plan for the Veneto Region. A total of approximately 543,000 simulations were performed across 3,932 spatial units defined by combinations of 56 soil types, 15 climatic zones, 17 crops, and four irrigation regimes. Business-as-Usual scenarios were compared with selected AECMs, including conservation agriculture, organic farming, maintenance of permanent pastures and meadows, buffer strips, manure injection, and optimization of fertilization and irrigation practices. Simulated environmental indicators included CO₂ and N₂O emissions, soil organic carbon (SOC) dynamics, NO₃- leaching, and NH₃ volatilization. Results highlighted strong spatial variability in the effectiveness of the evaluated measures and revealed trade-offs among environmental objectives. No single AECM consistently maximized benefits across all indicators. Conservation agriculture produced the largest SOC increases, particularly in intensively cultivated lowland areas. Permanent pastures and meadows showed the most balanced environmental performance in mountainous regions, simultaneously improving multiple indicators. Optimization of fertilization practices achieved the greatest reductions in NO₃- leaching, while organic farming generated more variable

responses, with site-dependent effects on GHG emissions and soil erosion. Ensemble outputs further enabled the identification of areas characterized by higher inter-model agreement and regions where uncertainty remained substantial. These findings highlight the potential of agri-environmental-climatic measures to reduce environmental pressures through the substitution of conventional high-input practices with more sustainable management strategies. Ensemble modelling proved effective in identifying where such measures can deliver the greatest environmental benefits while accounting for structural uncertainty, thus supporting evidence-based implementation of CAP interventions at the regional scale.

Sustainable barley production: effects of biochar and microbial biostimulants under reduced mineral nitrogen fertilization

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Abstract ID: 162

Session: 2. SOSTITUZIONE

Presentation: Poster

Barley (*Hordeum vulgare* L.) is one of the most widely cultivated cereal crops worldwide and is mainly used for animal feed and malt production. Modern agriculture requires improved productivity while reducing environmental impact and optimizing resource-use efficiency. In this context, biochar and microbial plant biostimulants represent promising strategies to enhance crop resilience under reduced mineral nitrogen fertilization. The aim of this study was to evaluate the use of innovative fertilizers and microbial biostimulants to improve barley performance under reduced mineral nitrogen input conditions. A field experiment was conducted during the 2024–2025 growing season at the “L’Amaranto” farm located in Cadelbosco di Sopra, Reggio Emilia, Italy. Before sowing, 70% of the required nitrogen was supplied as cattle manure (50 t ha⁻¹). A single winter barley genotype, Nure, was selected for the trial, and five treatments were compared: (1) no additional nitrogen supplementation (control); (2) no additional nitrogen supplementation plus biochar application (0.5 kg m⁻² at sowing); (3) no additional nitrogen supplementation plus *Pseudomonas chlororaphis* seed inoculation; (4) no additional nitrogen supplementation plus biochar application (0.5 kg m⁻² at sowing) combined with *P. chlororaphis* seed inoculation; and (5) nitrogen supplementation to reach 100% of the standard nitrogen requirement through ammonium nitrate application at the end of tillering. The experiment was arranged in a completely randomized design with three replicates per treatment. Each replicate covered an area of 2 m² and consisted of five rows spaced 18 cm apart. A wheat border was sown around the experimental area to minimize border effects. An ultralight DJI Mini 2 drone was used to acquire aerial RGB images during the stem elongation stage. The images were analyzed to determine vegetation indices: the Green-Red Vegetation Index (GRVI) and the Visible Atmospherically Resistant Index (VARI). During stem elongation, leaf chlorophyll content was also estimated. At maturity, 1 m² from each replicate was harvested to evaluate aboveground biomass and yield components, including number of spikes m⁻², grain yield, and harvest index (HI). Data were subjected to one-way analysis of variance (ANOVA) using GenStat 17th Edition software, and mean comparisons were performed using Duncan’s test. *P. chlororaphis* seed treatment significantly increased leaf chlorophyll content (+8.5%) and hectolitre weight (+5%) compared with the untreated control, reaching values comparable to those obtained under standard nitrogen fertilization. *P. chlororaphis* treatment resulted in a 33% increase grain yield (2 t/ha) compared with the untreated control (1.5 t/ha), although it remained 20% lower than

the full nitrogen fertilization treatment (2.5 t/ha). Biochar increased dry biomass production (+46%) without translating into a grain yield increase. The combined application of biochar and PGPR did not reveal synergistic effects. In addition, GRVI and VARI values at stem elongation were significantly higher in the “100% standard Nitrogen” treatment than in the other treatments. Overall, the use of microbial biostimulants represents a promising and innovative approach to reduce dependence on mineral nitrogen fertilizers, decrease environmental impact, and improve the efficiency and sustainability of crop production systems, in line with current European Union agricultural and environmental objectives

Germination efficiency of soybean under temperature stress: seed lot-dependent response to *Chlorella*-based seed treatments

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Abstract ID: 164

Session: 2. SOSTITUZIONE

Presentation: Poster

Soybean acts as a key N-fixing break crop in European agriculture, and is increasingly cultivated in intensive and double-cropping systems. In these systems, rapid and uniform germination and establishment under temperature stress are essential to secure weed control and acceptable yields. Seed biostimulants derived from microalgae such as *Chlorella sorokiniana*, which provide phytohormone-like compounds and metabolites that support early growth, have been proposed to enhance germination and seedling vigor. However, the effectiveness of these biostimulants may depend on the seed lot's initial physiological quality and the type of stress. This study assessed whether *Chlorella*-based seed treatments improve soybean germination under standard and thermal stress conditions, with particular focus on seed lot-dependent responses. Two untreated seed lots of the cultivar EM Pura exhibiting contrasting physiological quality were selected. Lot 209 had high germination and vigor, while Lot 212 showed low germination and vigor. Seeds from each lot were subjected to four treatments: untreated control (NC), an intermediate dose (C1) and a high dose (C2) of a *Chlorella sorokiniana*-based biostimulant, and a commercial biostimulant serving as a positive control (PC). Standard germination, accelerated aging, and cold test were conducted according to ISTA protocols to serve as stress proxies, simulating optimal conditions, heat stress during late soybean sowings, and low-temperature stress during early sowings, respectively. The percentages of normal, abnormal, and dead seedlings were recorded and analyzed using a two-way ANOVA, with seed lot, treatment, and their interaction as fixed effects. Under standard conditions, lot 209 consistently demonstrated high germination across treatments, averaging 92.4% normal seedlings, while lot 212 averaged 52.9%, confirming the contrasting initial seed quality. In the low-quality lot, biostimulant treatments increased the proportion of normal seedlings from 37.5% in the untreated control to a maximum of 59.5% in C1; however, these gains did not raise germination above the typical germinability commercialization threshold of 80.0%. Accelerated aging resulted in the sharpest reduction in germination, particularly in lot 212, where normal seedlings frequently declined to low values regardless of treatment (mean = 23.1%). In contrast, in lot 209, PC and C1 treatments mitigated germination losses relative to untreated seeds, maintaining 61.0-62.5% normal seedlings, compared with approximately 41.0% in the untreated control. In both accelerated aging and cold test, C2 often performed worse than C1 and, in some cases, even worse than the untreated control, indicating that higher doses did not enhance efficacy and could be deleterious under severe stress. The seed lot-by-treatment interaction was significant in most analyses, indicating that treatment effects were strongly dependent on lot quality rather than uniform across seed material. These findings suggest that the agronomic efficiency of *Chlorella*-based soybean seed treatments

varies across seed lots. Moderate doses may support establishment in vigorous lots and under mild thermal stress, while high doses may be ineffective or detrimental in weaker lots, particularly under severe heat stress. Consequently, Chlorella seed treatments may enhance establishment efficiency in soybean rotations, but their application should be tailored to seed lot quality and sowing conditions rather than presumed to provide a uniform advantage.

A Twelve-Year Field Study on the Effects of Previous Crop Debris Management Through Tillage and Fungicide Application on Agronomic Traits and Regulated and Emerging Mycotoxin Contamination in Soft Wheat

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Abstract ID: 165

Session: 2. SOSTITUZIONE

Presentation: Poster

Occasional reduced tillage could be adopted also in intensive cereal systems to improve soil conservation and reduce operational costs. However, in maize–wheat rotations, the retention of previous crop residues on the soil surface may increase the risk of *Fusarium* head blight (FHB) and the accumulation of regulated and emerging mycotoxins in wheat grain. The aim of the study is to evaluate the effects of no-tillage, minimum tillage, ploughing, integrated of the fungicide application at flowering on wheat agronomic performance, fungal diseases, and contamination of regulated and emerging mycotoxins, under natural infection conditions in a high-yielding maize–wheat system. A 12-year field experiment (2011–2023) was conducted in the northern Italy under natural infection conditions with maize as previous crop. Crop residues management through tillage were compared throughout the study, according to a factorial design with fungicide application, considering their efficacy in growing seasons with a medium–low or high FHB risk. Fungal metabolites were assessed through multi-mycotoxin LC–MS/MS analysis. Ploughing minimized FHB severity by up to 81% under high disease risk conditions, whereas reduced tillage decreased foliar disease severity and prolonged canopy stay-green during grain filling. Ploughing increased grain yield by 6% compared with minimum tillage under medium–low FHB risk conditions, while no significant yield differences between tillage systems were observed under high FHB pressure, where disease severity became the dominant factor affecting crop performance. In contrast, no-tillage caused an overall additional 11% yield reduction compared with minimum tillage (Figure 1). Ploughing also ensured higher grain protein content than reduced tillage systems. Fungicide application significantly improved grain yield, with increases of 14% and 35% under medium–low and high FHB risk conditions, respectively, mainly through enhanced higher thousand kernel weight, while slightly reducing grain protein concentration. The contamination of regulated and emerging mycotoxins, as well as other fungal metabolites, was strongly influenced by both meteorological conditions and agronomic practices.

Ploughing reduced deoxynivalenol (DON) and zearalenone contamination by up to 75% and 60%, respectively, while fungicide application achieved comparable reductions. No significant differences between no-tillage and minimum tillage were observed for DON and associated *Fusarium* metabolites. Emerging mycotoxins, particularly moniliformin and enniatins produced by other *Fusarium* species, were consistently detected in all growing seasons and significantly increased under reduced tillage. Although detected at lower concentrations, both minimum tillage and no-tillage also increased contamination by toxins produced by *Alternaria* species, whereas ergot alkaloids increased only under no-tillage conditions when detected. Reduced tillage in maize–wheat systems represent a viable but risk-sensitive agronomic strategy for wheat safety and quality. Integrated and adaptive cropping systems combining residue management and targeted fungicide application, with further agronomic elements, are essential to reconcile reduced tillage practices with grain productivity and food safety in intensive cereal systems.

Agronomic traits and nutritional features of importance in low-raffinose genotypes for added-value soybeans

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Session: 2. SOSTITUZIONE

Presentation: Poster

The presence of anti-nutritional factors (ANF) in legumes is an important challenge towards a higher incorporation of beans in our diet. In soybeans, the oligosaccharides belonging to the raffinose family (RFO), stachyose, raffinose and verbascose, are of interest, as they are resistant to heating treatments and limit the use of soybeans in high value food and feed applications. To overcome these constraints, low RFO-lines have been recently developed. The study was carried out in the river Po Plain in North-West Italy over two growing seasons, 2022 and 2023. Different soybean genotypes were cultivated for two consecutive years under the same agronomic conditions, by comparing 3 pre-commercial genotypes proposed by the seed supplier as low-RFO cvs (NAV346, NAV555 and NAV290), with other 7 ones selected within those already available within added-value food and feed supply chains. In brief, these cvs were characterized by specific qualitative and distinctive traits such as the white colour of hilum (5 cvs: PR91M10, P18A02, Brillante, Cecilia, EM Pura) or low- trypsin inhibitor content (2 cvs: Bahia and Radiosa). The total content of RFO in low-RFO cvs was very low in both growing seasons, with values of less than 0.4 and 0.2 g 100 g⁻¹ in 2022 and 2023, respectively. In comparison to the average concentration present in the other genotypes, the total concentration of RFO in these new cvs was six and eleven times lower in 2022 and 2023, respectively. In both years, the low-RFO cvs reported a yield potential, similar or higher than that of the control genotypes belonging to the same maturity group; furthermore, they showed a good seed dimension and test weight, and a high protein content (>42%). Low-RFO cvs had trypsin inhibitor activity comparable to those of the conventional genotypes. This study showed that the novel pre-commercial cvs NAV555 and NAV290, developed using traditional breeding techniques, have great potential as new added-value genotypes with significantly low RFO concentrations. Furthermore, these genotypes showed consistently low values of RFO, albeit still with growing-season effects. The nearly complete reduction of RFO, secondary metabolites with known beneficial roles in the defense and growth of the plant, did not result in a decrease in the plant's vigor or productivity. Moreover, the reduction in RFO seem to be associated in a protein content higher than that of conventional cvs commonly used within high-value food and feed applications, without a higher occurrence of other ANF such as TI. These results highlight the potential for the establishment of new added-value supply chains devoted to the specialized feed and food application industries. The extremely low RFO content of the cvs NAV555 and NAV290, combined with the high protein content and kernel size, can add substantial

value to the feed chains of monogastric animals (pigs and poultry), aquaculture, pet food and also can be a significant advantage for soybean intended for food use.

Safe-and-Sustainable-by-Design nitrogen nanofertilizers: objectives and agronomic framework of the Nano2U project

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Abstract ID: 188

Session: 2. SOSTITUZIONE

Presentation: Poster

Global agricultural production relies heavily on nitrogen (N) fertilization, yet conventional N fertilizers are still associated with low nitrogen use efficiency (NUE) and substantial environmental losses via nitrous oxide emissions and nitrate leaching. While precision agriculture has improved fertilizer placement and timing, further progress requires innovative formulations able to better synchronize N release with crop demand. In this context, second-generation nanofertilizers represent a promising frontier, provided that their development integrates agronomic performance, environmental compatibility, and occupational safety from the earliest stages of design. The INAIL BRIC2025 Nano2U project is a two-year research project coordinated by the University of Udine, with Luca Marchiol serving as Principal Investigator. Nano2U adopts a Safe-and-Sustainable-by-Design (SSbD) framework to develop bio-based urea nanocarriers and assess their potential contribution to more efficient and safer N fertilization strategies. The scientific consortium comprises the University of Udine, CNR Nanotec, and the University of Rome Tor Vergata, and is complemented by the involvement of the designated INAIL Operational Unit in the project's executive phase. In addition, FCP Cerea is formally associated with the project as an industrial stakeholder, contributing expertise in fertilizer production, formulation development, analytical control, and technology transfer. This structure is intended to connect nanomaterial design, occupational safety assessment, agronomic evaluation, and potential industrial scalability within a common SSbD-oriented research framework. Within the scientific consortium, CNR Nanotec is responsible for the development and physicochemical characterization of bio-based nanocarriers derived from waste biomasses, including chitosan-based matrices integrated with nanocellulose or hydroxyapatite to modulate urea release. The University of Rome Tor Vergata conducts in vitro safety assessments using human cell models relevant to occupational exposure, focusing on respiratory, cutaneous, and immune targets. The University of Udine leads the agronomic component, which aims to establish the experimental basis for evaluating fertilizer performance, N dynamics, and potential environmental losses under controlled field-scale conditions. The UniUD activity launching in October 2026 will focus on Italian ryegrass (*Lolium multiflorum* Lam.) as a model forage crop, managed under a split-applied N fertilization regime totaling 150 kg N ha⁻¹. Trials will be conducted using drainage lysimeters, enabling the monitoring of soil–plant–water N dynamics and the quantification of nitrate leaching.

Crop nutritional and physiological status will be assessed through non-destructive measurements, including gas exchange, chlorophyll-related indices, and optical sensing. At harvest, biomass production and plant N partitioning will be measured to calculate agronomic efficiency indicators, including N uptake efficiency, N utilization efficiency, and overall NUE. By presenting the objectives and agronomic framework of Nano2U, this contribution aims to inform the agronomic community about the role of field-oriented assessment in the responsible development of nanotechnology-enabled fertilizers. The project is expected to provide a methodological bridge between material design, safety evaluation, agronomic relevance, and industrial transfer, supporting the transition of second-generation N nanofertilizers from laboratory concepts to scientifically grounded agricultural applications.

Brassica juncea as a Cover Crop for Green Manure: Optimization of incorporation time in the southern Po Valley

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Abstract ID: 189

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Presentation: Poster

Green manure is an ancient agronomic practice that has regained considerable relevance in contemporary crop rotation systems, particularly, though not exclusively, in organic farming. The widespread decline or complete disappearance of livestock across many Italian agricultural districts has critically reduced the availability of organic matter inputs essential for long-term soil fertility maintenance. Green manure represents at least a partial solution to this deficiency. The present research relates on germplasm derived from almost forty years of expertise in Brassicaceae breeding at CREA, Research Centre for Cereal and Industrial Crops (Bologna, Italy). The use of Brassicaceae species as green manure crops in northern Italy is particularly strategic given their limited representation in conventional local rotations. Within the southern Po Valley the incorporation of *Brassica juncea* into cropping sequences offers multiple agronomic and ecological benefits: enhanced rotational biodiversity through the introduction of genera and species phylogenetically distinct from the dominant crops; a deep taproot system promoting subsoil decompaction and nutrient cycling; significant attractiveness to pollinators during the flowering period; and substantial contributions of green biomass and total nitrogen to the soil. This last aspect is particularly relevant given the growing concerns about declining soil fertility and the emerging geopolitical instabilities that are affecting the continuity of supplies and prices of synthetic fertilizers. The field trial was conducted during the 2024-2025 growing season, with autumn sowing and mechanical chopping followed by soil incorporation at full bloom stage in April 2025. Four *Brassica juncea* cultivars were compared for vegetative development and biomass production: three varieties developed by CREA-CI (ISCI20, ISCI99, and ISCI100 Red) and one advanced breeding line (FL). Plant growth was monitored in both above and below-ground fractions across four phenological stages: rosette, stem elongation, floral bud development, and full flowering. At each assessment, fresh biomass samples were collected and oven-dried for determination of total nitrogen (N) and total carbon (C) content. The investigations carried out helped in identification of the optimal phenological stage for green manure incorporation

to maximize soil organic matter inputs while accounting for the timing requirements of the subsequent cash crop. Quantification of total nitrogen contributed by green manure further allows for precise calibration of fertilization inputs for the following crop, thereby reducing unnecessary production costs and minimizing the risk of nutrient oversupply. Finally, embedding these parameters into a long-term monitoring framework could directly support compliance with EU fertilization regulations, including the Farm to Fork Strategy and the Nitrates Directive.

SOILRES Tailored Crop Sustainable Management through Biodiversity-Based Soil Health

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Session: 2. SOSTITUZIONE

Presentation: Poster

SOILRES aims to enhance soil health and boost crop resilience by integrating biodiversity-based strategies into sustainable agricultural practices. Responding to the urgent need for climate-smart, environmentally friendly farming systems and supporting EU policy objectives, the project co-creates practical and scalable innovations together with farmers, advisors, researchers and policymakers. Farmers were involved from the very beginning, already during proposal development, and remain central to the work, as all innovations are tested directly in their fields under real production conditions. The project is structured around six Use Cases deployed across seven demonstration sites representative of the main crops and pedoclimatic zones of Europe: Atlantic (Denmark; wheat-barley), Boreal (Finland; wheat-oats-rapeseed intercrop), Continental (France; wheat-forage), Pannonian (Hungary; wheat-winter pea-soybean) and Mediterranean (Italy; wheat-legumes-sunflower, and Portugal; maize). Each Use Case combines soil-improving inputs, microbial bioinoculants, biostimulants, green manure, biochar, seed coating and on-farm compost-derived biostimulants, with agroecological practices tailored to the local context, including crop diversification and perennialisation, cover crops and cover-crop mixtures, intercropping and automated strip cropping and crop-livestock coupling, living mulch, permanent soil coverage and minimum tillage. A central pillar of SOILRES is its integrated monitoring and modelling framework, designed to capture the agronomic, biological and environmental responses to these innovations across diverse agro-ecosystems. Field-level monitoring combines soil biodiversity assessment, tracking the diversity and activity of soil organisms, with measurements of soil quality and soil functions, linking biological indicators directly to agronomic outcomes such as crop establishment, yield and nutrient-use efficiency. Environmental performance is quantified alongside agronomic gains to evaluate trade-offs and synergies. Beyond plot-scale measurements, the project deploys remote sensing for scaling up observations from the field to the landscape. These multi-source data converge into coupled soil-plant-climate models that simulate system behaviour under current and future climatic conditions, enabling prediction of long-term soil health trajectories and identification of the most effective practice combinations for each pedoclimatic zone. This harmonised monitoring chain, spanning in-field sensors, soil sampling, satellite observation and modelling, allows consistent, cross-site benchmarking from the Boreal north to the Mediterranean south, and supports an integrated assessment of innovation performance. Through national task forces for stakeholder engagement, dedicated work on business models and replicability, and a strong communication and dissemination effort, SOILRES translates these results into tailored, transferable crop management recommendations. The expected outcome is a portfolio of validated, biodiversity-based and data-driven solutions that improve soil health, strengthen crop resilience to climatic stress, and offer

farmers practical, economically viable pathways toward sustainable production across Europe's diverse pedoclimatic conditions.

Weed seed viability in post-anaerobic digestate and its influence on soil seed bank germination

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Session: 2. SOSTITUZIONE

Presentation: Poster

The increasing interest in circular economy approaches has promoted the use of digestate, a byproduct of anaerobic digestion, as an organic amendment and fertilizer in agricultural systems. Digestate offers agronomic benefits including high nutrient availability and improved soil fertility, and its use aligns with current European strategies aimed at reducing dependency on synthetic inputs. However, concerns remain regarding the possible dissemination of viable weed seeds through digestate application, as the biomass fed into biogas production plants may introduce weed seeds into the digestion process. Whether these seeds survive thermophilic anaerobic digestion and whether digestate influences the soil seed bank are still open questions with practical implications for weed management in agricultural fields. Therefore, this study had two aims: to evaluate the presence of viable weed seeds in digestate intended for agricultural application, and to assess whether digestate application influences the germination of weed species potentially present in the soil seed bank. Digestate samples were collected from two biogas facilities located in Rovigo province (Northern Italy), both operating under thermophilic conditions (44–47°C). Unseparated digestate, separated solid and liquid fractions, cattle slurry, and poultry manure were included in the study. All matrices were chemically characterized. Two greenhouse experiments were conducted at the experimental farm "Lucio Toniolo" of the University of Padova using sterilized soil to avoid seed bank interference. In the first experiment, matrices were mixed with sterilized soil and monitored for spontaneous seedling emergence over approximately four months. In the second experiment, 100 seeds per replicate of three weed species: *Abutilon theophrasti* Medik., *Amaranthus retroflexus* L., and *Sorghum halepense* (L.) Pers. were added to the treated soil to evaluate the potential stimulatory effect of the matrices on germination. Statistical differences were analysed by a two-way factorial ANOVA, followed by a Tukey post hoc test. To evaluate the relationship between the chemical characteristics of the tested matrices and their effect on weed seed germination, a Spearman rank correlation analysis was performed. No weed seedling emergence was observed in any replicate of the first experiment, suggesting that thermophilic anaerobic digestion effectively devitalized weed seeds present in the tested matrices. In contrast, the second experiment revealed that all tested matrices significantly increased weed seed germination compared to the untreated control, with correlation analysis indicating total nitrogen content as the main germination promoter. Both the unseparated digestates and liquid digestates exhibited significantly higher germination promotion

compared to cattle slurry and poultry manure, while the separated solid fraction showed germination promotion comparable to these conventional organic fertilizers. These results indicate that while digestate does not appear to introduce viable weed seeds directly, its application may stimulate the germination of seeds already present in the soil seed bank, potentially increasing weed pressure in treated fields. These findings highlight the importance of evaluating not only seed viability in digestate, but also its indirect effects on weed dynamics, and have practical implications for the agronomic management of digestate in both conventional and organic farming systems.

Sustainable exploitation of *Gracilaria gracilis* biorefinery residue as foliar biostimulant for organic durum wheat

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Abstract ID: 204

Session: 2. SOSTITUZIONE

Presentation: Poster

In recent years, macroalgae have increasingly attracted interest as a primary source of bioactive natural compounds and biomaterials. *Gracilaria gracilis*, a red seaweed naturally present in the Lesina Lagoon (Southern Italy), is characterized by high potential productivity. Previous studies demonstrated that *Gracilaria gracilis* could serve as an interesting source of natural porous agar material and phycobiliproteins. According to the biorefinery concept, the protein-rich residue obtained from consecutive extraction processes could be valorized as an agricultural input. In organic durum wheat cultivation, widely practiced in the Mediterranean area, nitrogen supply is the main factor affecting yield, protein content, and grain technological quality. However, organic nitrogen is often applied only at sowing, and delayed mineralization during spring can result in insufficient availability during key phenological stages. Macroalgae-based biostimulants can help the crop overcome this limitation through both nutritional functions and stimulation of physiological processes. This study evaluated the effects of *Gracilaria gracilis* extract from the residue obtained from consecutive extraction processes, applied as foliar treatment on organic durum wheat (cv. Cappelli) during the 2025 growing season. Field trials were conducted in two contrasting environments of the Capitanata area (Apulia region, Southern Italy): Tavoliere (plain) and Sub-Appennino (hill), characterized by different rainfall and temperature patterns, with the former being drier, especially during grain filling. Beside the control (D0, without *Gracilaria gracilis* treatment, two foliar applications were performed (one at flag leaf emergence and one week later), using two concentrations: 5% (D1; 0.5 L extract in 9.5 L H₂O) and 10% (D2; 1.0 L extract in 9.0 L H₂O), both at approximately 1 L per 10 m². Both fields received standard organic fertilization practices. A randomized complete block design with four replications was adopted. At harvest, grain yield, protein content (N × 6.25), and gluten protein aggregation (via size-exclusion chromatography) were determined. Results showed that *Gracilaria gracilis* treatment significantly increased grain yield in

both environments (Fig 1 A), with D1 being more suitable in the plain site (3.7 vs. 2.7 t ha⁻¹ for D1 and control, respectively) while D2 performing better in the hill site (3.35 vs 1.96 t ha⁻¹, for D2 and control, respectively). Protein content increased notably in the hill environment with *Gracilaria gracilis* treatments, rising from 10.2% (control) to 12.9 under D2 and 14.0% under D1, representing a valuable outcome for organic systems typically characterized by low grain protein. Conversely, not significant protein variations were observed in the plain environment (Fig. 1B). Regarding to gluten protein aggregation level, *Gracilaria gracilis* treatment improved the unextractable polymeric protein (UPP) fraction, with environment-specific responses: D2 significantly increased UPP in the plain (33.4% vs 27.8% for D2 and control, respectively), while D1 was more effective in the hill environment (27.2% vs 21.5% for D1 and control, respectively). These preliminary results demonstrate the potential of *Gracilaria gracilis* extract as a sustainable biostimulant for organic durum wheat. A second year of trials is currently underway, which is essential to confirm these findings given the evident environmental influence on qualitative parameters.

Arbuscular Mycorrhizal Biostimulant (Resid GR4T) Enhances Crop Performance and Resilience in Greenhouse and Field Trials

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Abstract ID: 205

Session: 2. SOSTITUZIONE

Presentation: Poster

ABSTRACT: Arbuscular mycorrhizal fungi (AMF) biostimulants enhance crop resilience to abiotic stress and nutrient use efficiency. Resid GR4T (APQ-4-2), a granular inoculant containing *Glomus iranicum* var. *tenuihypharum*, was evaluated for improving yield stability under water and nutrient limitations in several raw and veggie crops. The study assessed Resid GR4T effects on plant growth, physiology, and yield under greenhouse and field conditions. Greenhouse trials on cucumber (Germany) and wheat/spelt (UK) used sterilized soil and tested 2.5–15 kg/ha versus untreated controls. Field trials on winter wheat, barley, and corn (Spain) applied 10–20 kg/ha in replicated plots under standard management. Parameters measured included yield, biomass, chlorophyll index (SPAD), water-use efficiency, AMF root colonization, and nutrient content (P, Zn). Data were analyzed by ANOVA with LSD ($p < 0.05$) as a main separation test. Resid GR4T consistently outperformed controls. In greenhouse cucumber, 10 kg/ha increased fruit weight by 18% (204 g vs 173 g). Winter wheat field trials showed modest but significant yield gains (~5%). Treated plants exhibited strong AMF colonization (absent in controls) and trends toward improved P and Zn uptake. In water-limited barley, treated plots, maintained yield and showed slightly higher intrinsic water-use efficiency, indicating improved drought response. Resid GR4T effectively establishes AMF symbiosis in several crops, resulting in moderate productivity gains and enhanced nutrient uptake, with indications of improved stress tolerance. These findings support AMF biostimulants as tools for climate-smart agriculture, warranting further optimization of application strategies to maximize yield and resilience. **KEYWORDS:** biostimulants; arbuscular mycorrhiza; nutrient uptake; drought tolerance; field trials; crop resilience.

Phosphate-Solubilizing Bacillus Biostimulant Utrisha™ P Boosts Oilseed Rape Yield Under Reduced Phosphorus Fertilization

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Abstract ID: 206

Session: 2. SOSTITUZIONE

Presentation: Poster

ABSTRACT: Phosphorus (P) fertilization inefficiency in agricultural soils contributes to nutrient losses and yield gaps, as much of applied P is rapidly immobilized and unavailable to crops. Biostimulant solutions based on phosphate-solubilizing bacteria (PSB) aim to improve P use efficiency and maintain crop yields with lower P inputs, supporting sustainable production in the face of finite phosphate resources. This study tested Utrisha™ P (BIO_STML_0060), a *Bacillus subtilis*/B. megaterium PSB inoculant, for its ability to enhance crop P uptake and yield under reduced P fertilization. Multi-site field trials across Europe (2023–2024) included winter oilseed rape (OSR). Crops received Utrisha P at 0.15 or 0.20 L/ha applied either in-furrow at planting or broadcast post-emergence, with P fertilizer reduced to 30–75% of normal rates. Agronomic (yield, quality), spectral (NDVI), and plant P uptake parameters were measured and analyzed by ANOVA (LSD $p < 0.05$). OSR yields responded positively to Utrisha P: treated plots yielded +5–9% versus untreated controls across sites, with an example of 3.6 t/ha vs 3.3 t/ha (+9%). Yield gains were most evident when Utrisha P was applied in early spring rather than at planting. No crop injury or quality reduction occurred in any treatment. Utrisha P can safely improve OSR yields under reduced P fertilizer, demonstrating a modest yet consistent boost to nutrient use efficiency. This suggests PSB inoculants are a promising tool for agronomic-smart nutrient management, helping farmers maintain yield with less P input. **KEYWORDS:** biostimulant; phosphate-solubilizing bacteria; nutrient use efficiency; oilseed rape; low phosphorus; sustainable agriculture

Maize Response to Poultry Bone-Derived Nano-Hydroxyapatite as an Alternative Phosphorus Fertilizer

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Abstract ID: 209

Session: 2. SOSTITUZIONE

Presentation: Poster

The limited availability of phosphate rock and the low efficiency of conventional phosphate fertilizers represent major challenges for sustainable agriculture. In soil, applied phosphorus is often rapidly immobilized, reducing plant availability and increasing the risk of nutrient accumulation and aquatic eutrophication¹. Within the PRIN project CLEOPATRA (2023–2026), this study evaluates a circular-economy strategy for phosphorus fertilization based on waste-derived nano-hydroxyapatite (nHAP) obtained from poultry bone residues, alone or in combination with phosphate-solubilizing bacteria (PSB). Nano-hydroxyapatite was synthesized from poultry bone waste through a top-down approach involving thermal treatment at 300 °C or 700 °C, followed by mechanical milling. This process generated two distinct formulations, hereafter referred to as nHAP300 and nHAP700. A pot experiment was conducted under semi-controlled conditions using maize (*Zea mays* L.) grown to physiological maturity in sandy loam soil. Eight treatments were compared: unfertilized control, triple superphosphate (TSP), nHAP300 and nHAP700, each tested with or without inoculation with *Pseudomonas allopuntida*. Fertilized treatments received an equivalent phosphorus dose of 80 kg P ha⁻¹, with five replicates per treatment. Plant growth, phenology, yield components, grain quality, tissue elemental composition, photosynthetic parameters and spectral indices were monitored throughout the crop cycle. The different fertilization strategies induced distinct patterns of biomass allocation and plant response. TSP increased the harvest index, reaching values of approximately 0.34–0.36, and promoted greater allocation of biomass to grain production. By contrast, nHAP300 enhanced total plant dry biomass and increased shoot growth by approximately 10–15% compared with the unfertilized control. nHAP700 showed intermediate responses, broadly comparable to those observed under TSP fertilization. Kernel P concentration and total plant P accumulation were similar among fertilized treatments, although nHAP300 tended to promote slightly higher whole-plant P uptake. Spectral measurements further indicated improved canopy vigor under nHAP300, as shown by higher NDVI values and lower ARI1 indices, suggesting reduced physiological stress. Overall, poultry bone-derived nHAP supported maize growth, P nutrition and grain quality at levels comparable to conventional TSP fertilization, while valorizing an animal by-product within a circular-economy framework. Under the tested conditions, *Pseudomonas allopuntida* inoculation did not significantly enhance plant performance, indicating that the benefit of PSB inoculation may depend on soil conditions, microbial establishment or P availability dynamics. These results support

the potential of waste-derived nHAP as a sustainable phosphorus fertilizer and highlight the need for further validation under field conditions to assess agronomic performance, nutrient-use efficiency and environmental benefits across soil–crop systems.

Agronomic Evaluation of Different Types of Poultry Manure and Frass

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Abstract ID: 215

Session: 2. SOSTITUZIONE

Presentation: Poster

The increase in food demand is driving an increasing use of mineral fertilizers, which also increase costs and environmental risks. The use of organic fertilizers represents a sustainable alternative to synthetic inputs. To evaluate the performance of innovative organic fertilizers, a short-term incubation experiment was made in combination with a pot trial to investigate nitrogen mineralization and availability for crops. Four organic materials were evaluated: two derived from chicken manure: with a standard diet (PM-STD) vs. with a diet enriched with bioactive compounds obtained from the exuviae of *Hermetia illucens* grown on olive pomace (PM-BC); and two types of *H. illucens* frass: with a spent grain diet spent grain (F-STD) vs. with olive pomace diet (F-POM). The materials were applied at different nitrogen levels: 100% from organic (100), 66% organic + 33% mineral (66/33Min), 33% organic + 66% mineral (33/66Min), 100% mineral (100Min), as well as a control without N (0N) and a treatment with a double dose of N from organic (200). Soil incubation was made in a growth chamber (25 °C) for 72 days. In parallel, biological validation was performed in a greenhouse on *Diplotaxis tenuifolia* L. grown in pots (12 cm diameter). In both experiments, NH_4^+ , NO_3^- , and enzymatic activity were measured, while plant biomass was also measured in the pot experiment. At the end of the incubation period, both poultry manures showed total nitrate concentrations not different from those of the mineral treatment (137.9 mg/kg). Only PM-BC showed lower values (101.4 mg/kg), though these were not different from the unfertilized control. In contrast, frass showed marked nitrate immobilization when net nitrate levels were calculated. The most pronounced negative values were observed in treatments where the N supply came exclusively from the organic matrix, particularly with F-POM, which recorded peaks ranging from -2.16 to -35.86 mg/kg of N- NO_3 . The cumulative biomass data confirmed the incubation data with rocket yield correlated with N- NO_3 availability. The best results were obtained with the double organic dose for poultry manure (1.6 and 1.4 kg/m² for PM-STD and PM-BC, respectively) and with the organo-mineral mixture 33/Min66 for frass (1.3 and 1.2 kg/m² for F-STD and F-POM, respectively), likely due to a priming effect of the mineral fraction on soil microbial metabolism. The study highlights significant variability in N release among the different soil amendments, underscoring the

importance of evaluating their behaviour in the soil. The integrated approach—soil incubation and pot test with plants—proved effective for optimizing crop nitrogen nutrition, demonstrating how organo-mineral mixtures can efficiently substitute synthetic fertilizers, since provide a not different nitrate availability for crops.

Essential oils as natural agents for organic seed coating: control of seed-borne and soil-borne fungal pathogens

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Abstract ID: 222

Session: 2. SOSTITUZIONE

Presentation: Poster

Seed treatment is an effective strategy to protect seedlings from infections during germination, emergence, and early growth. Although synthetic fungicides remain the most widely used tools for controlling fungal diseases, public concern arises about their direct and indirect impacts on the environment and on human health. In this context, natural products, such as essential oils (EOs), may provide a sustainable alternative for seed treatment, contributing to the development of organic, resilient and low-impact agricultural practices. Within FilOBio project, funded by MASAF, the study aims to evaluate the efficacy of six selected EOs as organic seed-coating against soil-borne and seed-borne fungi affecting herbaceous crops (e.g. *Cicer arietinum* L., *Pisum sativum* L., *Lupinus albus* L., *Phaseolus vulgaris* L. and *Carthamus tinctorius* L.). Firstly, tea tree (*Melaleuca alternifolia* Cheel.), eucalyptus (*Eucalyptus globulus* Labill.), bergamot (*Citrus bergamia* Risso), lavender (*Lavandula angustifolia* Moench.), oregano (*Origanum vulgare* L.), and cinnamon (*Cinnamomum verum* J. Presl) EOs were tested by in vitro assays for their ability to affect mycelial growth and pathogenicity of *Fusarium oxysporum* f. sp. *ciceris*, *F. oxysporum* f. sp. *pisi*, *F. oxysporum* f. sp. *phaseoli*, *Colletotrichum lupini* and *C. chrysanthemi*. EOs were prepared at 1% v/v in an aqueous solution containing 0.1% Tween 20 v/v as emulsifier. Two in vitro assays, based on diffusible and volatile compounds, were conducted on PDA medium in Petri dishes under controlled conditions to evaluate the antifungal activity of EOs due to their soluble and volatile compounds. Results showed that among the six tested EOs, oregano and cinnamon EOs, significantly reduced the growth of all fungal strains whereas the other EOs showed no inhibitions. Moreover, volatile compounds were generally more effective than diffusible ones in suppressing fungal mycelial growth. Subsequently, oregano and cinnamon EOs were studied through a phytotoxicity test to determine whether their use as seed-coating of chickpeas, peas, lupins, beans and safflower might affect seed vitality and germination parameters (germination percentage, seedling vigour index, radicle and shoot length, radicle and shoot fresh and dry weights). Seeds treated with EOs were sown in sterilised sand trays, while sterile water was used as control treatment. Germination percentage was considered as the main indicator of phytotoxicity, while seedlings morphology was assessed to identify developmental abnormalities. The treatments did not negatively affect germination parameters, suggesting a good compatibility at the tested concentration. Finally, in vivo assay was performed to evaluate the protective activity of the EO-based seed coating against pathogens under soil conditions. Seeds treated by soaking were sown in artificially inoculated soil, and germination percentage and mean germination time were

recorded. Results suggested that EOs provided only limited protective activity under soil conditions. This outcome may be related to several factors, including insufficient concentration of active compounds, limited contact time between EOs and seeds, degradation of volatile components, and differences in seed coat permeability among species. Overall, these results highlighted the promising antifungal potential of oregano and cinnamon EOs as sustainable seed-coating agents. Therefore, future investigations are needed to translate the promising laboratory outcomes into practical and sustainable agricultural solutions.

From depleted soil to productive tomato: integrated vermicompost-mineral fertilisation improves yield, fruit quality and soil recovery

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Abstract ID: 226

Session: 2. SOSTITUZIONE

Presentation: Poster

The progressive loss of soil organic carbon is a major constraint for intensive horticulture, particularly in systems that depend on repeated mineral fertilisation but operate on soils with poor organic matter and limited nutrient retention. This study evaluated whether buffalo manure-derived vermicompost could partially replace mineral nitrogen in a lettuce-tomato cropping sequence established on a carbon-depleted sandy loam soil. The soil initially contained only 0.98% organic matter and 0.078% total nitrogen. After a short preliminary lettuce crop, the same amended soil was used for tomato (*Solanum lycopersicum* L. cv. KIMBERLINO F1, UnigenSeeds Italy) cultivation, a fruiting crop with greater and more continuous nutritional requirements during vegetative growth, flowering, and fruit filling. Six fertilisation strategies were compared, ranging from unfertilised control and full mineral nitrogen to increasing levels of vermicompost substitution, using 210 kg N ha⁻¹ as the reference nitrogen input for tomato. Tomato responded strongly to fertilisation. Marketable yield increased from 3.3 kg m⁻² in the unfertilised control to 7.4-7.5 kg m⁻² under full mineral fertilisation and 25% vermicompost substitution, corresponding to an increase of about 130-140%. Fruit number followed the same pattern, rising from 67.5 fruits plant⁻¹ in the control to 157-160 fruits plant⁻¹ in the best-performing mineral-supported treatments. Higher vermicompost substitution levels reduced marketable yield to 6.0, 5.1, and 5.3 kg m⁻² at V50, V75, and V100, respectively, indicating that complete replacement of mineral nitrogen was insufficient to sustain maximum tomato productivity in the short term. Nevertheless, partial substitution allowed a substantial reduction in mineral nitrogen use while maintaining high yield performance. Fertilisation strategy also affected fruit quality and metabolism. Mineral-supported treatments improved fruit firmness, colour parameters, nitrogen status and amino acid accumulation, with total free amino acids reaching 259.2 µmol g⁻¹ FW under full mineral fertilisation compared with 122.8 µmol g⁻¹ FW

under full vermicompost substitution. Intermediate strategies modulated quality-related traits more favourably. In particular, V50 was associated with higher lycopene, polyphenols, glucose, starch, proteins and proline, while V75 showed higher fructose, soluble solids and essential amino acids. These responses suggest that integrated fertilisation did not simply sustain yield but also redirected carbon and nitrogen metabolism in ways relevant to fruit nutritional and technological quality. The sustainability assessment identified V25 and V50 as two complementary partial-substitution strategies. Compared with full mineral fertilisation, V25 maintained maximum marketable yield, around 7.4–7.5 kg m⁻², reduced mineral N input by 25%, and slightly increased the economic margin by about 1.3%, while raising soil organic matter from about 1.1% to 1.2%. V50 provided a more soil-oriented balance: it halved mineral N input and increased soil organic matter to about 1.4%, corresponding to a 27% gain over full mineral fertilisation, while maintaining 6.0 kg m⁻² yield and limiting the economic margin reduction to about 21%. Thus, V25 was the best option for preserving yield and profitability, whereas V50 offered a stronger compromise between productivity, fertiliser reduction and soil recovery.

Effects of Biochar and *Trichoderma harzianum* on Yield and Physiological Traits of Lettuce (*Lactuca sativa* L.)

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Abstract ID: 238

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Presentation: Poster

MIIn intensive horticultural systems, the use of organic amendments and microbial biostimulants represents a strategy of considerable interest to improve soil fertility and support crop productivity. In this context, biochar, a carbon-rich material obtained from biomass pyrolysis, can contribute to improving the soil physico-chemical properties, nutrient availability, and crop growth. At the same time, the microbial biostimulant based on *Trichoderma harzianum* M10 can promote vegetative development and plant–soil interactions. Therefore, the objective of the trial was to evaluate the effect of biochar, M10, and their combination on the productive and physiological performance of two varieties of butterhead lettuce (*Lactuca sativa* L.) over two crop cycles. The experiment was carried out at the Department of Agricultural Sciences in Portici. The plants were grown in pots inside a plastic greenhouse, at a density of 8 plants m². Two crop cycles were carried out: in the first, autumn-winter cycle, the variety ‘Malyeva’ was used, transplanted on 11 November 2024 and harvested after 67 days; in the second, winter-spring cycle, the variety ‘Volare’ was used, transplanted on 20 January 2025 and harvested after 84 days. Four treatments were compared: i) untreated control, ii) treatment with biochar, iii) treatment with M10, and iv) treatment with biochar + M10. Each treatment was replicated three times, for a total of 12 pots for cycle. Biochar was incorporated into the soil before transplanting, while M10 was applied at transplanting by immersing the seedlings roots in a microbial suspension, followed by a second application through fertigation after 15 days. At harvest, the lettuce heads were cut and weighed, then they were cleaned and again weighed to obtain the marketable yield. Other productive parameters were recorded, including number of leaves, mean leaf weight, as well as some and physiological indicators, including SPAD value. The results showed a general improvement in productive performance in the treated plants compared to the control, with an average increase of 12% in the first cycle and 18% in the second one. Among the treatments, the biochar + M10 combination determined an increase in marketable weight of 16% and 26%, in the first and second cycle, respectively, compared with the control. Regardless of the product applied, the second cycle showed greater overall plant growth compared with the first cycle (+41%). This trend was confirmed by the increase in mean leaf weight, 10 g and 14 g, and by fresh stem weight, 19.7 g and 26.0 g, in the first and second cycle, respectively. From a

physiological point of view, the SPAD value was higher in the treated plants, with average increases of approximately 9% (first cycle) and 10% (second cycle). This result suggests a possible improvement in the vegetative status and photosynthetic activity of the treated plants. Overall, the preliminary results indicate that the biochar + M10 combination may represent a promising strategy to improve lettuce productivity in short-cycle horticultural systems. However, it will be necessary to integrate the interpretation of the productive and physiological data with the qualitative and nutraceutical analysis of lettuce.

Thermal Performance of Biodegradable Films and Charcoal-Based Products in Soil Solarization

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Abstract ID: 239

Session: 2. SOSTITUZIONE

Presentation: Poster

Soil solarization represents a valuable practice for controlling soil-borne pathogens and improving soil microclimatic conditions. This technique is currently gaining renewed relevance due to the increasingly stringent European regulatory framework, such as Regulation (EC) N. 1107/2009, which has restricted the use of chemical fumigants. However, the recent need to make agricultural practices more sustainable is pushing for alternatives to the use of traditional plastic, that has the well-known issues related to their disposal. Consequently, the use of biodegradable films for soil solarization may offer a promising alternative strategy, contributing to the reduction of plastic waste accumulation as well as agrochemical inputs. The aim of the study was to evaluate the effectiveness of biodegradable films for soil solarization, also in combination with a charcoal-based product (Solin®), by assessing their effects on soil heating. The experiment was carried out in 2025 at the Department of Agricultural Sciences of the University of Naples Federico II, Portici, Italy. Two biodegradable films, PC25F9/35 and PC25T28/35, a conventional polyethylene film, and a non-solarized control, were compared. The solarization treatments were applied either alone or in combination with Solin®, a product designed to increase solar radiation absorption. Before film application, the soil was tilled and irrigated up to field capacity; then, probes were installed at a depth of 20 cm to continuously monitor soil temperature. The results showed that all solarized treatments increased the average soil temperature by approximately 27% compared with the non-solarized control, which never exceeded 34 °C. The biodegradable solarizing films allowed soil temperatures to exceed the critical threshold of 38 °C, which is considered important for the biocidal effect against soil-borne pathogens. The integration of Solin® strongly enhanced the thermal performance of the solarization system; in particular, under the polyethylene treatment, heat accumulation above 38 °C was up to four times higher than in the corresponding treatment without Solin. At the end of the solarization period, a reduction in soil organic matter, up to 26%, and total nitrogen, expressed as N-Kjeldahl, was observed, probably due to the intensification of mineralization processes promoted by the high temperatures. Overall, the study highlights that biodegradable films either alone or in combination with Solin®, may represent a promising strategy to improve soil thermal conditions.

This approach can be considered a sustainable agronomic solution, in line with the need to reduce the use of chemical inputs and the accumulation of plastic residues in protected cropping systems.

Field-scale evaluation of NNI- and NDVI-based variable-rate nitrogen fertilization in no-till durum wheat under Mediterranean conditions

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Session: 2. SOSTITUZIONE

Presentation: Poster

A field-scale experiment was conducted during the 2024–2025 growing season at the Baccoleno farm of Tonino Congiu in Asciano (Siena, Italy; 43.202322° N, 11.583604° E), within the AGRIP-RES project (SRG09, Regione Toscana), to compare different nitrogen management approaches in no-till durum wheat (*Triticum durum* Desf., cv. Matusalem). The site is representative of the rainfed cereal-growing areas of Central Italy and has been managed under conservation agriculture practices for several years. The trial was established on a commercial field of approximately 20 ha. The field was divided into 12 experimental units (1.0–2.0 ha) and randomly assigned to three nitrogen management strategies with four replications per treatment: (i) conventional fixed-rate fertilization (CONV), (ii) variable-rate fertilization based on the Nitrogen Nutrition Index (NNI), and (iii) variable-rate fertilization based on NDVI measurements calibrated through an N-rich strip (NDVI). Nitrogen applications were adjusted according to the decision rules associated with each strategy and implemented using variable-rate technology. Durum wheat was grown under no-till conditions following Egyptian clover (*Trifolium alexandrinum* L.) and managed according to Integrated Pest Management principles. Grain yield, grain protein concentration, thousand-kernel weight (TKW), and economic return were assessed at harvest. Yield data were obtained from combine harvester yield maps and validated through six field sampling points within each experimental unit. Nitrogen management significantly affected grain yield. The NNI-based strategy achieved the highest productivity (4.05 t ha^{-1}), significantly outperforming both CONV (3.56 t ha^{-1}) and NDVI (3.47 t ha^{-1}). Compared with conventional management, NNI increased grain yield by 0.49 t ha^{-1} (+13.7%), whereas NDVI resulted in a slight reduction (-0.09 t ha^{-1}). Grain protein concentration was not significantly affected by fertilization strategy and ranged from 11.24% to 11.35%. Likewise, TKW did not differ significantly among treatments, ranging from 31.47 to 32.49 g. Economic analysis highlighted the superiority of the NNI approach, which generated an additional net return of approximately $\text{€}161 \text{ ha}^{-1}$ compared with the conventional strategy. In contrast, the NDVI-based approach resulted in a slight economic loss ($-\text{€}27 \text{ ha}^{-1}$). Furthermore, NNI achieved these results with a modest reduction in nitrogen fertilizer use, whereas NDVI did not provide measurable fertilizer savings relative to conventional management. Notably, the NNI-based strategy achieved grain yields exceeding 4.0 t ha^{-1} despite being implemented under no-till conditions. Yield levels

were comparable to those generally observed in conventionally tilled durum wheat fields of the same area during the 2024–2025 growing season ($3.5\text{--}4.0\text{ t ha}^{-1}$), highlighting the potential of conservation agriculture systems to maintain competitive productivity when supported by effective nitrogen management. Under the environmental conditions of Central Italy, NNI-based fertilization proved more effective than both conventional management and the NDVI-rich strip approach, increasing grain yield and profitability while slightly reducing nitrogen inputs. These results support the adoption of crop-based nitrogen diagnostics as a practical decision-support tool for improving nitrogen use efficiency in conservation agriculture systems. Keywords: durum wheat, precision agriculture, nitrogen fertilization, nitrogen nutrition index, NDVI, N-rich strip, conservation agriculture, nitrogen use efficiency.

Traditional and innovative soil solarization: effects on soil temperature and nitrogen dynamics in protected horticultural systems

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Abstract ID: 243

Session: 2. SOSTITUZIONE

Presentation: Poster

Soil solarization is an agronomic practice based on increasing the temperature in its upper layers by covering it with plastic films that have high transmissivity to solar radiation. This technique is generally applied during the summer months and allows for the reduction of soil pathogenic microorganisms by reaching high temperatures, particularly above 38 °C, which are considered effective for thermal soil disinfection. On the other hand, the use of chemical fumigants for soil disinfection in protected cultivation systems is currently subject to increasingly strict regulatory restrictions and temporary derogation authorizations, granted only in the presence of specific phytosanitary emergencies. Therefore, it is necessary to identify alternative, sustainable solutions capable of ensuring adequate containment of soil-borne pathogens while improving the environmental and management compatibility of intensive horticultural systems. In this context, we evaluated the effects of traditional solarization and an innovative system based on the application of a black liquid charcoal-based product, Solin®, sprayed on the soil surface after pre-solarization irrigation, with the aim of creating a coating capable of increasing solar radiation absorption. The trial was conducted under a tunnel in two horticultural farms located in Battipaglia and Bergamo, comparing three treatments: i) non-solarized soil (NS), ii) soil subjected to traditional solarization (S), and iii) soil subjected to solarization with spray application of Solin (S+S). Soil temperature dynamics were monitored using probes installed at 20 cm depth, while representative soil samples were collected before film laying and after film removal to determine organic matter (OM), Kjeldahl nitrogen (N-tot), nitrate nitrogen (NO₃-N), and ammonium nitrogen (NH₄⁺-N). In the Battipaglia site, the total duration of solarization was 37 days (11 June-18 July 2025), whereas in the Bergamo site solarization was carried out from 30 July to 27 September 2025, for a total of 60 days. In Battipaglia, solarization resulted in a marked increase in the average soil temperature compared to the non-solarized control, with average values of 42.1 °C in the two solarized treatments vs. 32.1 °C in NS. Moreover, only the solarized treatments reached temperatures above 38 °C, functional to the

sanitizing effect of the treatment. In Bergamo, the thermal increase was less intense but still evident, with 34.8 °C in the solarized treatments compared to 29.0 °C in NS. The use of Solin showed a site-specific behavior: in Battipaglia, it did not further increase thermal accumulation compared to traditional solarization, while in Bergamo, it favoured higher temperatures in the different temperature ranges considered. As regards the soil chemical properties, OM and N-tot showed limited variations, while NO₃-N increased after solarization, suggesting enhanced organic matter mineralization induced by higher soil temperature and moisture conditions. Overall, the results indicate that solarization significantly modifies the soil microclimate and nitrogen dynamics, with effects depending on the site and climatic conditions. The innovative system with Solin may represent a promising strategy to improve the efficiency of solarization, although further investigations are needed to clarify its actual effectiveness across different pedoclimatic contexts.

Conservation Agriculture and Earth Observation for Durum Wheat Resilience in Mediterranean Environments: Results from a Long-Term Field Experiment

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Abstract ID: 244

Session: 2. SOSTITUZIONE

Presentation: Poster

Climate change is intensifying drought frequency and severity across Mediterranean agro-ecosystems, threatening the sustainability of cereal-based cropping systems. Intensive tillage further intensifies soil vulnerability by reducing water retention and accelerating organic matter loss. Conservation Agriculture (CA), through minimum tillage (MT) and no-tillage (NT), offers a mechanistically sound strategy to enhance soil health and crop resilience. Long-term experimental evidence under real field conditions remains limited. This study aims to quantify the agronomic and environmental performance of MT and NT on durum wheat (*Triticum durum* Desf.) over multiple seasons, integrating Earth Observation (EO) with ground-based measurements to capture soil-plant-climate interactions at field scale. A long-term field trial (2014–2026) was established at the CREA-CI "Manfredini" experimental farm (Foggia, southern Italy), a representative site of the semi-arid Mediterranean environment. Treatments (MT, NT) were arranged in a randomized complete block design with four replicates on ~1 ha elementary plots. Multi-temporal satellite imagery from Landsat 8 and Sentinel-2 was processed in Google Earth Engine, deriving spectral vegetation indices (NDVI, EVI, OSAVI, MCARI, NDTI) across key phenological windows. EO data were correlated with field measurements including grain yield, plant biomass, canopy height, Leaf Area Index (LAI), phenological staging, and grain quality traits (protein content, gluten index, test weight). Soil organic carbon and soil moisture were monitored as key edaphic drivers. EO - derived indices demonstrated good correlations with ground-truth observations across all seasons, validating the multi-temporal satellite approach for long-term CA monitoring. NT consistently showed higher VIs values than MT, during between stem elongation and grain filling, reflecting superior canopy vigor and drought resilience. This response could be attributed to enhanced soil moisture conservation under residue cover, which limits evaporative losses during physiologically critical growth stages. NT durum wheat yield exhibited greater inter-annual stability and a consistent, albeit moderate, advantage under water-deficit conditions respect to MT. Preliminary evidence links these performance gains to

progressive increases in soil organic carbon content and improved water retention capacity, suggesting cumulative benefits of NT over time on soil fertility. The long-term integration of multi-temporal EO data with field-scale agronomic and soil measurements provides a powerful framework for monitoring CA effects under Mediterranean drought conditions. Preliminary results confirm NT as an effective strategy to enhance crop resilience and yield stability in semi-arid environments. The dataset generated supports improved calibration of remote sensing models and contributes to the development of precision agriculture and decision-support tools for sustainable dryland management.

Microbial consortia for improving resource use-efficiency and tomato resilience to abiotic stress under open-field conditions

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Abstract ID: 252

Session: 2. SOSTITUZIONE

Presentation: Poster

Improving the efficiency of agricultural input use is a strategic priority for enhancing the sustainability and competitiveness of cropping systems, particularly in the face of increasingly severe abiotic stresses, including drought, salinity, and extreme heat, which substantially constrain global agricultural productivity. Among the available biological solutions, microbial consortia are emerging as innovative biostimulants capable of enhancing crop performance by optimizing plant physiological processes and strengthening soil-plant-microbiome interactions, while simultaneously reducing reliance on external agricultural inputs. However, field-based experimental evidence remains limited and fragmented, hindering a robust assessment of their effectiveness and restricting the large-scale adoption of these technologies. This systematic literature review, following PRISMA 2020 guidelines, comprehensively screened Scopus records (articles, reviews, book chapters) on microbial biostimulants across crops, identifying 1,096 papers. Only 7 studies (30 treatments) met inclusion criteria for open-field tomato experiments using specifically microbial consortia under abiotic stress – revealing critical field evidence scarcity. Microbial consortia delivered robust benefits for tomato under field abiotic stress, with yield increases in 76.9% of area-based measures (mean yield increase of +94.1% vs. non-inoculated controls) and 85.7% of per-plant assessments (mean +481.0% fruit fresh weight gain). Fruit quality (Brix° or total soluble sugars) improved in 46.2% of cases (mean +65.6%), driven by stress mitigation and antioxidant synergy. Specific consortia enabled up to 50% irrigation reductions and lower phosphorus inputs without yield penalties; however, variable responses and incomplete nutrient application data across studies limited definitive mechanistic conclusions. These findings underscore microbial consortia as promising tools for enhancing tomato yield under field abiotic stress – offering farmers practical protection against climate impacts. Yet the scarcity of studies and methodological diversity preclude robust synthesis and predictive deployment of consortia. Future multi-site, multi-year trials with

standardized core metrics are essential for their reliable, large-scale adoption in sustainable agriculture.

Sustainable nutrition strategies for durum wheat in Mediterranean area

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Abstract ID: 255

Session: 2. SOSTITUZIONE

Presentation: Poster

Durum wheat is one of the main crops in Mediterranean countries. A major nutritional problem in its cultivation lies in nitrogen application: excessive or poorly timed nitrogen leads to several issues, while insufficient nitrogen results in low protein content. Nitrogen use efficiency (NUE) in wheat is often below 50%, causing substantial environmental losses and increasing costs for farmers. In addition, phosphorus immobilisation represents another critical aspect. In this context, new nutritional systems based on microgranular fertilisers and biostimulants offer alternatives for more effective and sustainable durum wheat management. Optimising fertiliser rate, timing, and form, along with integrated nutrient management, is critical to producing wheat that is both high-yielding and nutritionally balanced. The study evaluated sustainable nutritional strategies based on plant growth-promoting microorganisms (PGPR), nitrogen-fixing bacteria, and biostimulants, compared with conventional fertilisation, on the ecophysiological and productive response of durum wheat (*Triticum turgidum* var. durum). A field experiment was carried out in Apulia (Gravina in Puglia, Southern Italy) during the 2024/2025 growing season on a silty-clay loam soil. A strip-plot design with three replications was adopted, combining four varieties with three fertilisation treatments: unfertilised control; conventional mineral fertilisation (12/24 at sowing, ammonium nitrate with sulphur at tillering and heading); and two sustainable treatments (microgranular fertilisers ILSA 6/16 or Umostart 11/48 at sowing, plus a microbial consortium at heading containing *Azospirillum brasilense*, *Bacillus amyloliquefaciens*, *Trichoderma longibrachiatum*, *Azotobacter chroococcum*, and mycorrhizae). Drone flights equipped with thermal and multispectral sensors effectively distinguished treatment effects. In February, ILSA gave better NDVI values. By late May, no statistical differences remained, but canopy temperature showed a strong negative correlation with yield ($R^2 = 0.69$). Foliar biostimulants improved photosynthetic activity significantly over untreated controls. Umostart prolonged canopy greenness, while ILSA led to earlier senescence. GNDVI at heading (April) correlated positively with final yield ($R^2 = 0.63$). Varietal differences were modest, but some varieties showed better late-season vigour. Regarding productive response, conventional and sustainable fertilisation outperformed the unfertilised control (3.5 t ha^{-1}) with an average 20% increase. Among fertilised treatments, the highest yields were registered by conventional application and the Umostart-plus-microbial combination (4.78 and 4.73 t ha^{-1}), significantly exceeding ILSA alone (4.03 t ha^{-1}). One variety stood out for protein quality, another for lowest non-vitreous kernels. Correlations between drone indices and yield were significant: GNDVI in April explained 63% of yield variability; canopy temperature in June ($R^2 = 0.69$) showed a negative relationship with yield,

indicating that more productive plots were cooler due to higher transpiration. Microbial biostimulants improved nutrient use efficiency and crop resilience to thermal and water stress. In conclusion, maximising yield and quality of durum wheat requires integrated, multi-stage nutritional management. Basal fertilisation with Umostart is the primary driver of productivity, while foliar coverage with microbial consortia enhances quality. Drone-based multispectral and thermal monitoring proves essential for precision agriculture, objectively validating different nutritional strategies.

Evaluation of Sheep Wool Pellet Application in Baby Lettuce (*Lactuca sativa* L.) Cultivation: Agronomic, Physiological, and Quality Effects of an Innovative Organic Fertilizer

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Abstract ID: 257

Session: 2. SOSTITUZIONE

Presentation: Poster

Modern agriculture is increasingly required to reduce its dependence on synthetic mineral fertilizers, whose use is associated with significant environmental and economic concerns. In this context, the valorisation of agro-livestock by-products represents a strategy consistent with the principles of circular economy and sustainability. Among these, sheep wool, often considered a low-value residual material, exhibits particularly promising characteristics for agronomic use due to its high organic nitrogen content and its ability to improve the physical properties of the growing substrate. The aim of this study was to evaluate the effectiveness of sheep wool pellets as an organic fertilizer in baby lettuce (*Lactuca sativa* L.) cultivation, assessing their potential as a total or partial alternative to conventional mineral fertilization. The experiment was conducted under protected conditions in the experimental greenhouse of the University of Salerno using potted baby lettuce cv. Eden. Ten treatments were compared: an unfertilized control, a control fertilized with ammonium nitrate, and eight sheep wool pellet treatments differing in particle size (>5 mm and <5 mm), application rate, and combinations with mineral fertilizer. The experimental design was arranged as a randomized complete block with three biological replicates per treatment. Throughout the growing cycle, physiological parameters (chlorophyll, flavonol and anthocyanin contents, NDVI, leaf area, and leaf temperature), agronomic traits (plant height, stem diameter, fresh and dry biomass, and root development), and quality attributes (leaf colour and nitrate content) were monitored. The results demonstrated that sheep wool pellets effectively supported baby lettuce growth, leading to significant increases in the main vegetative parameters compared with the unfertilized control. In particular, treatments receiving equivalent pellet doses, as well as those combining pellets with mineral fertilizer, achieved fresh and dry biomass values comparable to or higher than those obtained with conventional fertilization. Plants treated with sheep wool pellets also exhibited improved physiological status, associated with greater photosynthetic efficiency and a gradual release of nitrogen into the substrate. From a quality perspective, lower nitrate concentrations were

observed in pellet-fertilized plants compared with those receiving only mineral fertilizer, indicating improved nitrogen-use efficiency and enhanced product quality. In conclusion, sheep wool pellets proved to be a promising slow-release fertilizer capable of combining productivity, product quality, and environmental sustainability. Their adoption could contribute to the valorisation of a locally available livestock by-product while reducing the use of synthetic fertilizers and supporting the transition toward more resilient and circular agricultural systems.

Agronomic evaluation of different biostimulants on processing tomato through integrated and digital approaches

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Abstract ID: 263

Session: 2. SOSTITUZIONE

Presentation: Poster

The increasing frequency of abiotic stresses associated with climate change represents one of the main challenges for processing tomato production, negatively affecting vegetative growth, physiological efficiency, yield, and fruit quality. In this context, biostimulants are gaining increasing importance as products capable of enhancing plant resilience and resource-use efficiency, thereby contributing to the sustainability of agricultural systems. The aim of this study was to evaluate the effectiveness of different biostimulation strategies in open-field processing tomato production. The experiment was conducted at a commercial farm in the province of Salerno (Southern Italy) and compared several types of biostimulants, including humic substances, protein hydrolysates, seaweed extracts, rhizosphere microorganisms, and mineral formulations, with an untreated control. The effects of the treatments were assessed through a multidisciplinary approach integrating physiological, agronomic, productive, and qualitative measurements with digital agriculture techniques. Physiological parameters related to photosynthetic activity and leaf pigment content were monitored, together with morphological and productive traits of the crop and fruit quality parameters such as pH and soluble solids content (°Brix). In parallel, multispectral image analysis was used to calculate the vegetation indices NDVI and NDREI for non-destructive monitoring of the vegetative and nutritional status of the plants. The results showed that biostimulant application improved the physiological status of the plants, promoting greater vegetative vigor, improved nutrient-use efficiency, and enhanced tolerance to abiotic stresses. These effects translated into higher marketable yield and a greater percentage of commercial fruits compared with the control treatment. The main fruit quality parameters did not show significant differences, maintaining the standards required by the industry. Vegetation indices confirmed the field observations, highlighting spatial and temporal variations associated with the different treatments. Overall, the findings confirm the potential of biostimulants as effective products for improving productivity, resilience, and sustainability in processing tomato production, and demonstrate the added value of integrating traditional agronomic techniques with digital agriculture tools for more efficient crop management.

Evaluation of Bioherbicidal Efficacy of Powders from Agro-Industrial By-Products: Weed Control and Phytotoxicity in Tomato.

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Abstract ID: 265

Session: 2. SOSTITUZIONE

Presentation: Poster

Modern agriculture faces new challenges due to increasing limitations on synthetic pesticide application; notably, the “Farm to Fork” strategy aims to reduce their use by 50%. These chemical formulations pose severe risks to human health and ecosystems; consequently, finding sustainable alternatives is essential for managing agricultural biotic stressors. Among these, weeds are highly critical, drastically reducing crop yields through resource competition. Sustainable control methods counteract these impacts, balancing eco-friendly practices and agricultural productivity. Agro-industrial by-products are currently investigated for their bioherbicidal properties, as they release allelochemicals that inhibit weeds. Therefore, a pot experiment was carried out at the greenhouse of Foggia University to evaluate the allelopathic potential of bergamot (*Citrus bergamia* (Risso) Risso & Poit) and pomegranate (*Punica granatum* L.) dried peel powders incorporated into the growing substrate, alongside the EP5 commercial powder, containing 5% citric acid. The study assessed the powder effects on the germination and early development of three tomato-associated weeds, namely *Amaranthus retroflexus* L., *Chenopodium album* L., and *Solanum nigrum* L., as well as their possible phytotoxicity on the crop. Processing tomato plants (*Solanum lycopersicum* L., “Tyson” variety) were grown in 1.5-L pots filled with a commercial substrate, under either weedy or weed-free conditions, on either treated or untreated substrate. 30 seeds of each weed were sown per pot and 3.0 g of each powder was incorporated into the substrate three days after sowing, followed by watering to restore the pot water holding capacity. One tomato seedling was transplanted per pot four days after the treatment. The experiment was set up according to a completely randomized factorial design (three weed species × three powder types × sixteen replicates, for a total of 144 experimental units). Substrate moisture content was kept constant at the water holding capacity, by restoring 100% of evapotranspiration losses, measured daily by weighing the pots, and the experiment was terminated 45 days after transplanting. The number of germinated weed seeds was recorded every two days and, at the end of the experiment, the length and dry matter content of roots, shoots, and total plants of both tomato and weeds were measured. A set of germination- and growth-related parameters, namely final germination percentage (FGP), mean germination time (MGT), germination index (GI), seed vigor index (SVI), plant length inhibition (PLI), and biomass accumulation inhibition (BAI), were determined. Neither tomato germination nor plant length and dry matter were affected by the

powders and, similarly the PLI and BAI. Bergamot slightly promoted root dry matter, while pomegranate enhanced root length. Conversely, the powders exerted a strong allelopathic effect against the three weeds, especially regarding germination parameters, effectively halving the FGP, increasing the MGT, and reducing both GI and seedling SVI. The powders also had an inhibiting effect on weed root length, resulting in shorter weed plants compared to the untreated controls, and root dry matter. Results showed the allelopathic efficacy of the tested powders against the target weeds, particularly in limiting seed germination. Their inhibitory efficacy could be enhanced by precisely timing the application to effectively target emerging seedlings.

Impact of Fresh and Soil-Aged Biochar on the Yield of Unfertilized and Nitrogen-Fertilized Swiss Chard.

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Abstract ID: 266

Session: 2. SOSTITUZIONE

Presentation: Poster

In the context of sustainable crop production, amending soil with biochar represents a strategic approach to enhance soil fertility, increase nutrient availability and promote plant growth. Biochar has been widely studied with most existing research focused on short-term experiments; however, evaluating the long-term agronomic benefits due to aging dynamics of biochar in amended soils is of high interest. The aim of this study was to evaluate the effects of biochar aging (B), fertility management (F) and nitrogen rate (N) on the yield of Swiss chard (*Beta vulgaris* L. var. *cycla*). To this purpose, a greenhouse pot experiment was carried out during 2026 at the University of Basilicata, Potenza (40°38'N - 15°48' E, 819 m a.s.l.), Italy. Following a long-term series of experiments, the soil used in the study consisted of an unamended control (B0) and a soil amended with 2% (w/w) woody biochar five years prior (aged biochar, Ba). Specifically, both B0 and Ba came from a last experiment on sweet pepper. A portion of the B0 soil was amended with 2% (w/w) of woody biochar just before Swiss chard transplanting (fresh biochar, Bf). Treatments (B0, Ba and Bf) were split into two fertilization management groups: unfertilized soils (Fr) to evaluate the residual fertility from the previous experiment on sweet pepper treated with three N rates (0, 70, and 140 kg N ha⁻¹) and newly fertilized soils (Fn) testing three N rates (0, 100, and 200 kg N ha⁻¹) (N0, Nhalf and Nfull, respectively). Two plants per pot were grown in plastic pots (13×13×24 cm) filled with 2 kg of experimental soil, using a randomized complete block design with four replicates. Plants were watered every 2-3 days and two marketable leaf harvests were performed at 22 and 36 days after transplanting. At each harvest, biometric parameters (plant height, leaf number, surface area, fresh weight and dry weight) and chemical characteristics (total N, NH₄⁺ and NO₃⁻ content) were determined. Additionally, soil samples were analysed for total C, total N, NH₄⁺ and NO₃⁻ content. A non-significant biochar aging (B) effect on the total leaf fresh weight (TFW, as the sum of the first and second harvests) was observed. Conversely, fertilization management (F) was significant, with Fn resulting in higher TFW than Fr. As expected, the nitrogen rate (N) also exerted a significant effect; specifically, Nhalf and Nfull produced higher TFW compared to N0, while not differing from each other. Regarding the interaction B × F × N, Nhalf and Nfull consistently increased TFW. Particularly, this increase occurred in B0-Fn compared to B0-Fr and similarly in Ba under both fertilization managements. In Bf, higher TFW were observed under Nfull regardless of the fertilization management; however, under Fr, Nfull did not significantly differ from Nhalf, averaging a TFW of 44 g pot⁻¹ (corresponding to 26 t ha⁻¹). These findings suggest that biochar effects on yield may level

off over time; however, under fresh soil amendment, nitrogen availability remains the primary driver for Swiss chard yield.

The introduction of Self-Reseeding Cover Crop Under the Vine: A Living Lab Approach to Weed Management in Vineyards

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Session: 2. SOSTITUZIONE

Presentation: Poster

Soil tillage is still a widely adopted technique within organic viticulture to ensure effective weed control under vine rows. However, its repeated use has negative effects on soil fertility and generates consistent environmental and economic impacts due to increased greenhouse gas emissions and the sharp rise in fuel and lubricant prices over the last decade. Therefore, it is necessary to develop innovative agroecological strategies that enhance agrobiodiversity and offer affordable alternatives to reduce organic winegrowers' reliance on soil tillage. Nitrogen-fixing, self-reseeding species sown under the vine row could be a promising solution to reduce weed pressure without outcompeting with grapevines for soil water and nutrient uptake. During their cycle they can usually serve both as a living mulch – acting as a nitrogen supply for the companion crop – and as a dead mulch – because they die during summer, when most critical vine phenological stages occur. Moreover, since they exhibit a geocarpic growth habit, they can regrow in early fall, allowing the establishment of a long-lasting soil cover (3-4 years). Nonetheless, encouraging farmers to adopt complex agroecological practices is not an easy task, as it requires careful consideration of their needs and their willingness to change. Living Labs (LL) approaches are considered promising tools for overcoming these barriers and fostering innovation. Within this kind of framework, different actors are directly involved in co-designing and co-developing tailored, on-farm experiments with a transdisciplinary approach, enabling the identification of farm-related issues linked to the specific socio-economic context in which the farm is embedded. With this objective, an LL experiment was established on a sandy loam soil during the 2025-2026 season at Tenuta Montefoscoli in Palaia (Pisa, Italy) (43°33'54" N, 10°44'24" E) on an organically managed vineyard (cv. Vermentino). The vineyard is trained to a unilateral Guyot system, with a spacing of 2.30 m between rows and 0.8 m within rows. Unlike baseline practice, which consists of mechanized weed control under vine rows, weed suppression is achieved through the use of three living mulch treatments: *Trifolium subterraneum* ssp. *subterraneum* L. and *Trifolium subterraneum* ssp. *brachycalycinum* F.H.W. Morley, grown as sole crops; and a mixed stand composed of four self-reseeding species, including 80% subterranean

clovers (*Trifolium* spp.) and 20% *Medicago polymorpha* L. Each of the four treatments (3 treatments plus the baseline treatment) is replicated three times on alternate rows, for a total of 12 vine under rows (4 treatments X 3 randomized blocks). The soil seedbed was prepared manually by hoeing. Broadcast sowing was carried out by hand on 2nd January 2026 at a sowing rate of 100 kg ha⁻¹. Crop and weed total aboveground biomass were collected on 18th May 2026 at the vegetative peak of the living mulches to evaluate their potential for weed suppression. Crop and weed total aboveground biomass, percentage cover, weed community and biodiversity indexes, will be monitored throughout the three years of experimentation. Acknowledgements: this study has received funding from the Agroecology Partnership (Grant Agreement ID: 101132349), under the Sunrise Project.

Sustainable Agronomic Strategies and AMF Inoculation Modulate Polyphenol Profile in Cultivated Cardoon under Mediterranean Conditions

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Abstract ID: 272

Session: 2. SOSTITUZIONE

Presentation: Poster

Cultivated cardoon (*Cynara cardunculus* L. var. *altilis*) is a promising crop because of its high biomass productivity and its ability to accumulate bioactive compounds, particularly polyphenols. To address the major constraints affecting Mediterranean agroecosystems, notably water scarcity and declining soil fertility, arbuscular mycorrhizal fungi (AMF) are increasingly used to enhance nutrient uptake, improve plant resilience, and stimulate the biosynthesis of secondary metabolites. Within the PRIN 2022 project “Optimization of a sustainable cultivation model for the production of bioactive compounds in *Cynara cardunculus* var. *altilis* (BioAltilis)”, was evaluated the effectiveness of a cultivation model based on AMF inoculation combined with different agronomic strategies, including planting density and harvest timing, to improve the polyphenol quality of cultivated cardoon under typical Mediterranean stress conditions. Field experiments were conducted in two contrasting Mediterranean environments, Gela (Sicily) and Cerignola (Apulia), using a split-plot design with three replicates. Plant density (2 vs. 4 plants m⁻²) was assigned to main plots, whereas AMF inoculation (Myco+ vs. Myco-) was applied to subplots. In the Myco+ treatment, a commercial inoculum (AEGIS IRRIGA®, Italtollina S.p.A., Italy), containing *Rhizophagus irregularis*, *Funneliformis mosseae*, and a bacterial consortium, according to the manufacturer’s specifications,

was used. At both sites, durum wheat was the preceding crop and transplanting was performed in September 2023 at the four-leaf stage. The crop consisted of the open-pollinated line 'Altilis 41', selected by researchers at the University of Catania for its high biomass and phytochemical production potential. Plants were managed under a repeated-cut system aimed at stimulating regrowth from rhizome dormant buds, suppressing flowering and extending the vegetative phase. Seven consecutive harvests were performed over two growing seasons. At each harvest, basal and fully expanded leaves were collected and analysed by HPLC-DAD to determine the polyphenolic profile. Polyphenol composition was strongly influenced by the environment, with Cerignola generally showing higher concentrations of both caffeoylquinic acids and flavonoids than Gela. Plant density also affected polyphenol accumulation, although its effect varied with growing season and harvest stage. During the first season, lower density favoured the accumulation of major caffeoylquinic acids, whereas in the second season higher density promoted the highest concentrations of both caffeoylquinic acids and flavonoids. AMF inoculation exerted a less consistent effect than site and harvest timing, but tended to enhance the accumulation of selected polyphenols, particularly caffeoylquinic acids, under specific treatment combinations, especially in Gela and at lower plant density. Overall, environmental conditions and harvest timing emerged as the main drivers of polyphenol variability, while plant density and AMF inoculation acted as context-dependent modulators of these responses.

Spatial weed dynamics in Mediterranean vineyards: integrating inter-row cover cropping with intra-row management strategies under organic and conventional systems

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Session: 2. SOSTITUZIONE

Presentation: Poster

Sustainable weed management in Mediterranean viticulture demands site-specific agronomic strategies that reduce herbicide dependence without compromising suppressive efficacy. While cover crops are well-established tools for inter-row weed control, their capacity to modulate weed pressure across the vineyard floor, and particularly into the intra-row zone, remains poorly studied. This study, conducted within the framework of the Horizon Europe GOOD (AGroecOlogy for weedDs) project, investigates the spatial interaction between inter-row cover crop establishment and intra-row management strategies in terms of weed biomass suppression. Field trials were established in two commercial vineyards in Calabria (Southern Italy), one organically and one conventionally managed. At each site, three inter-row treatments were compared: (i) a *Vicia villosa* Roth and *Avena sativa* L. mixture inoculated with autochthonous arbuscular mycorrhizal fungi (AMF+), (ii) the same mixture without AMF inoculation (AMF-), and (iii) an untreated control with spontaneous vegetation (SV). Intra-row treatments included: (i) clover (*Trifolium alexandrinum* L.) sowing (CS), (ii) mechanical weeding (MW), and (iii) unmanaged spontaneous vegetation (USV). In the conventional vineyard, two additional intra-row treatments were included: full- and half-dose carfentrazone-ethyl herbicide (H100 and H50, respectively) applications. Inter-row cover crop plots (AMF+ and AMF-) and intra-row CS plots were sown in November 2025, with inoculum applied directly at sowing time. Weed coverage (Braun-Blanquet scale) and fresh and dry aboveground biomass were assessed in March and April 2026 via quadrat sampling. Preliminary statistical analysis, regardless of sampling date, indicated a spatial carry-over tendency in the organic system: adjacent inter-row cover crops, either AMF+ or AMF-, showed a consistent trend toward limiting weed expansion into USV strips,

suggesting a lateral suppressive effect on intra-row dynamics. Moreover, intra-row CS delivered effective weed suppression regardless of inter-row treatment across both management systems. In the conventional system, non-chemical intra-row practices (MW and CS) provided suppression levels comparable to herbicide (H100) applications, supporting their viability as non-chemical alternatives. These preliminary findings suggest that the vineyard floor functions as a spatially interconnected system in which inter-row and intra-row management are functionally coupled. Spatial combinations such as inter-row cover crops paired with intra-row clover show promise as herbicide-independent strategies for sustainable weed management in Mediterranean organic and conventional viticulture. Keywords: weed suppression, arbuscular mycorrhizal fungi, under-vine management, agroecology, herbicide reduction

Impact of the ban on unprotected urea on cereal crops in the Po Valley

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Abstract ID: 285

Session: 2. SOSTITUZIONE

Presentation: Poster

Under the EU environmental framework established by Directive (EU) 2024/2881 on ambient air quality and cleaner air for Europe, several Member States have progressively restricted or banned the use of conventional unprotected urea to reduce ammonia emissions. Italy is among them: the Resolution of the Council of Ministers of 20 June 2025 — National Action Plan for Air Quality Improvement — introduced a ban, effective from 2028, on applying unprotected urea in the Po Valley. In line with measures adopted or proposed by other Member States (including Germany, Ireland, and France), amendments in May 2026 allowed the use of inhibited or coated urea formulations, as well as alternative nitrogen fertilizers. According to a Nomisma study based on ISTAT data, urea accounts for 44% of nitrogen supplied through mineral fertilizers, making it the leading nitrogen source in cereal farming. Its dominance reflects three key advantages: lower cost per unit of nitrogen, high nutrient concentration (offering logistical benefits), and a more gradual nitrogen release compared with ammonium- or nitrate-based products. This paper summarizes an analysis of how urea use affects cereal production systems in the Po Valley and what replacing it with compliant alternatives means for farm productivity and profitability. Several substitutions scenarios were modelled: ammonium nitrate, ammonium sulfate, inhibited urea (NBPT, NPPT), coated urea, and inhibited urea applied via variable-rate technology. Each scenario was evaluated in term of grain yield in maize, common wheat, durum wheat, and rice. The nitrogen reference application rates were based on the standard recommendations established by the Italian National Quality System for Integrated Production for the four regions of the Po Valley. Table 1 summarizes the average 2025 nitrogen fertilizers market prices and the corresponding cost per unit of nitrogen. Results show that banning conventional urea leads to a marked increase in nitrogen costs across all alternatives. NBPT-treated urea exhibits the smallest increase in nitrogen unit cost. However, the total fertilization cost must also include field application cost, which depend on fertilizer nitrogen concentration, since lower N content requires higher product quantities and therefore greater machinery use. Table 2 reports the overall fertilization costs, including field application, for the three crops. Cost increases are the highest for ammonium nitrate, ammonium sulfate, and coated urea, while they remain lower for inhibited urea due to its unchanged nitrogen concentration. The adoption of variable-rate application technologies reduces nitrogen use by approximately 10–15% but these savings are offset

by an higher mechanization costs. In conclusion, the ban generates three main consequences: higher fertilization costs, which already represent the largest share of variable production expenses; more field applications when switching to fertilizers with lower nitrogen concentration; and greater logistical complexity due to larger fertilizer volumes. For cereal farms with limited access to nitrogen organic inputs, replacing unprotected urea may significantly reduce profitability and could accelerate a decline in domestic cereal production, particularly for maize, the key crop of the Italy's high-quality livestock supply chains.

Thirty years of organic and mineral fertilization affect maize yield and soil C stock, with strong site-specific responses

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Abstract ID: 291

Session: 2. SOSTITUZIONE

Presentation: Poster

Understanding SOM stability is essential for predicting SOC persistence and nutrient cycling, which sustain soil fertility and crop productivity. These processes underpin key agroecosystem services (AES), including food and feed provision and soil C sequestration, supporting food security for a growing global population and climate change mitigation. Although these AES are strongly influenced by fertilization management and pedo-climatic conditions, limited consideration has been given to the site-dependency of long-term management effects. We assessed the effects of thirty years of replacing mineral fertilization with farmyard manure in continuous maize systems across two contrasting pedo-climatic regions, evaluating two key AES: food and feed provision, as reflected by agronomic productivity, and soil C sequestration, assessed through SOC quantity, quality, and stability, integrating biological, physicochemical, and molecular indicators. Soil samples were collected in 2025 from two Long-Term Experiments (LTE), both established in 1992: Tetto Frati in NW Italy and AAFC in Ottawa, Canada, representing different environmental conditions, with a warmer climate (MAT 12.8°C) and a loamy soil (8% clay) in Italy, and a cooler climate (MAT 7.1°C) and a clay loam soil (36% clay) in Canada. Continuous maize for grain (MG) systems were evaluated to assess the effects of two N sources (MIN as urea and FYM as farmyard manure), each applied at two N input levels. Mean grain yield over the 2012-2024 period was used as an agronomic performance indicator. A 40-day laboratory incubation was conducted to quantify potentially mineralizable C. Particle-size physical fractionation was performed to separate SOM into coarse (>53 µm) and fine (<53 µm) fractions. Aggregate stability was evaluated using a slaking-based indicator as a measure of SOM physical protection, while the molecular composition of SOM was characterized by solid-state ¹³C nuclear magnetic resonance (NMR) spectroscopy to evaluate chemical stability.

Mean grain yield was nearly twofold higher at the Italian site than at the Canadian site (13.5 vs 7.1 t ha⁻¹), indicating a greater capacity to sustain food and feed provision. In contrast, the Canadian site showed a substantially greater capacity for long-term soil C sequestration, with SOC under MIN (and comparable N input levels) being ~70% higher in the Canadian than in the Italian soil, highlighting the strong influence of site-specific conditions. Long-term FYM application consistently increased SOC by ~40% compared with MIN at both sites. Site effects were also reflected in physico-chemical stabilization patterns, with a higher proportion of OC associated with the fine fraction (mineral-associated organic carbon, MAOC) in the Canadian soils (~90% SOC) compared with the Italian soils (~84%). Despite higher OC content in the Canadian soil, mineralizable CO₂-C per gram of SOC was ~50% higher in the Italian soil, suggesting greater biological activity and C availability, weaker protection and faster C turnover. Overall, our results quantify the role of fertilization practices in increasing soil C sequestration while supporting crop productivity, demonstrating that site conditions largely determine the relative performance of AES, and farmyard manure showed a site-specific effect by enhancing the AES that was inherently less expressed at each site.

Toward a competitive Wheat Ideotype: Dissecting constitutive and adaptive traits in wheat RILs under multi-level *Avena sativa* competition

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Abstract ID: 295

Session: 2. SOSTITUZIONE

Presentation: Poster

Introduction With the Green Revolution wheat varieties have been selected with a mutation of Reduced Height (Rht) dwarfing genes, allowing the intensive use of fertilizers with low risk of lodging for yield maximization. A drawback of this mutation is the lower tolerance to weed competition. Since herbicide efficacy is threatened due to resistant weeds, it is crucial to find new strategies that minimize herbicide use. One promising approach is to develop novel crop varieties with higher competitiveness to weeds. It is therefore pivotal to identify the most effective tolerance traits for competitiveness-oriented breeding programs. This study aims to identify constitutive and adaptive traits associated with greater yield stability and more effective weed suppression. A population of 45 recombinant inbred lines (RILs), derived from the cross between the soft wheat cultivars Lankaodali and Rebelde (*Triticum aestivum* L.), was evaluated. The RILs shows divergent morphological and phenological traits belonging from the parental lines. To assess adaptive elongation capacity, the population was screened under controlled conditions through gibberellic acid (GA₃) application and evaluated the elongation response. Based on PH, HD and GA₃ responsiveness, eight representative lines were selected for a field competition trial using *Avena sativa* as a model weed. The trial included weed-free plots and three increasing infestation levels, allowing the evaluation of genotype-specific responses to weed pressure. Wheat morphological traits, *A. sativa* density and fresh biomass were assessed to quantify plastic responses and weed suppression ability, while yield stability was evaluated to identify genotypes and traits associated with yield stability under increasing weed pressure. Results The RIL population showed wide variability in constitutive traits and GA₃ induced elongation response. Notably, GA₃ sensitivity was not strictly associated with plant height or heading date, suggesting that adaptive elongation capacity may segregate independently from constitutive traits linked to weed competitiveness. Among the tested genotypes, LkxRb_124r was the most responsive line to GA₃ and showed a strong morpho-physiological differentiation between control

and infested field conditions. This suggests a strong capacity to modulate growth in response to competitive stress. This marked plastic response was associated with greater yield stability and a stable suppressive ability against *A. sativa*. Specifically, LkxRb_124r reduced *A. sativa* plant density by 28.0% to 60.2% as infestation pressure increased, and fresh biomass by 61.8% to 57.3%. In contrast, Rebelde, which was insensitive to GA₃, showed limited tolerance and poor weed suppressive capacity, suggesting a weaker ability to adapt to competitive stress. Overall, LkxRb_124r emerged as the most promising genotype, as its competitive performance did not appear to only rely on a constitutive advantage, but rather on a strong adaptive plasticity associated with yield stability and effective suppression of *A. sativa*. across infestation levels. Conclusion The RIL population represents a valuable source of genetic and morpho-physiological variability for identifying traits involved in weed competitiveness. These results suggest that adaptive and plastic traits, often overlooked in modern breeding, should be reconsidered as key components of future breeding programs aimed at developing wheat lines with greater tolerance and competitive ability against weeds.

Conservation Tillage Drives Environmental Sustainability in Mediterranean Lentil–Wheat Rotations: A Life Cycle Assessment

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Abstract ID: 298

Session: 2. SOSTITUZIONE

Presentation: Poster

Background. Mediterranean cropping systems are increasingly challenged by climate variability while requiring lower environmental impacts without compromising productivity. Conservation agriculture, particularly reduced tillage and legume–cereal rotations, can improve resource-use efficiency and system resilience. However, the contribution of microbial biostimulants within these systems remains poorly quantified under field conditions. **Objective.** This study evaluated the environmental, agronomic and economic performance of a three-year lentil–durum wheat–lentil rotation under eight management scenarios generated by combining conventional tillage (CT) or sod seeding (SS), high (H; 100 kg ha⁻¹) or low (L; 70 kg ha⁻¹) lentil sowing density, and *Trichoderma harzianum* inoculation (TH) or untreated control (C). A sensitivity analysis comparing in-field residue chopping and baling was also performed. The experiment was conducted from 2020 to 2023 at a commercial farm in Poggiorsini (southern Italy) under rainfed Mediterranean conditions on silty loam soil. Conventional tillage involved mouldboard ploughing followed by secondary tillage, whereas sod seeding was performed directly on crop residues without soil disturbance. A cradle-to-farm-gate Life Cycle Assessment (LCA) was carried out following ISO 14040/44 standards using the ReCiPe 2016 method. The inventory included agricultural inputs, fuel consumption, machinery operations and crop residue management. Environmental performance was assessed through midpoint and endpoint indicators using two functional units: one hectare over the rotation cycle and one euro of gross revenue. Lentil yield data were analysed through a four-way factorial ANOVA, whereas durum wheat yield was analysed through one-way ANOVA. Residue management sensitivity analysis was performed using the GWP100 indicator. Soil management emerged as the dominant factor affecting environmental performance. Compared with CT, SS reduced Global Warming Potential by 40–60%, Terrestrial Acidification by approximately 15% and Fossil Resource Scarcity by about 20%, mainly because of lower fuel consumption and greater soil carbon retention. Conservation management consistently generated lower environmental burdens while maintaining or improving economic returns. The treatment combining sod seeding, *T. harzianum* inoculation and high sowing density (SS–TH–H) achieved the lowest endpoint damage scores and the highest gross revenue (€5,703 versus €4,334 for the least profitable CT scenario). However, differences among sod-seeding treatments were markedly smaller than those observed between tillage systems, highlighting the predominant role of soil management. Tillage significantly affected lentil yield, whereas no significant effects were detected for durum wheat. Residue chopping enhanced carbon

sequestration and improved GWP100 performance compared with baling, demonstrating the potential of conservation management to improve resilience under Mediterranean conditions. Conservation soil management was the principal driver of environmental and economic sustainability in Mediterranean lentil–wheat rotations. Sod seeding reduced environmental impacts while maintaining productivity and profitability, whereas higher sowing density and *T. harzianum* inoculation provided additional but secondary benefits. These findings support conservation agriculture as a key strategy for enhancing the sustainability and resilience of Mediterranean rainfed systems.

Session: 3.RI-PROGETTAZIONE

Strip intercropping as an agronomic approach for industrial biomass production on marginal land

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Abstract ID: 180

Session: 3. RI-PROGETTAZIONE

Presentation: Oral

Marginal lands are considered strategic areas for industrial crop cultivation within the framework of the European bioeconomy and climate-neutrality targets. In these environments, industrial crops may simultaneously provide biomass while promoting ecosystem services (such as carbon sequestration, or biodiversity enhancement). However, the sustainability and resilience of industrial crop cultivation depend on the adoption of low-input practices and diversified cropping strategies. This study evaluated a strip intercropping system including hemp, safflower, crambe and miscanthus under sloping marginal land (15% slope), in Ozzano dell'Emilia, BO. In Italy, slope represents the most common form of marginal land according to estimates from the EU-MIDAS project. The experiment was conducted from 2023 to 2025 using a strip plot design with three replicates and 600 m² plots. Each strip was 6-m-width to ensure compatibility with farm machinery and realistic management. Strips of miscanthus were fixed throughout the experiment, while the annual crops rotated according to a predefined sequence: crambe – safflower – hemp. As a result, the position of the neighboring crops was determined following the crop rotation. The objective was to assess crop interactions within the strip intercropping system and to evaluate the suitability of the four crops under sloping condition. No significant interactions among crops were observed in terms of yield, indicating that wide-strip intercropping can promote crop diversification without negatively affecting crop performance, even among species characterized by different competitive abilities. However, the four crops showed markedly different responses to slope. Hemp showed high adaptability and stability (CV = 26%), producing 12.8 Mg ha⁻¹ of above-ground biomass, comparable to values reported under favorable conditions (11-14 Mg ha⁻¹). Crambe showed good adaptability, with seed yields of 1.6 Mg ha⁻¹ comparable to favorable conditions (1.8-2.8 Mg ha⁻¹), with a CV of 34%. Safflower exhibited the lowest adaptability, with average seed yields of 1.1 Mg ha⁻¹, approximately 50% lower than those commonly reported under favorable conditions (seed: 1.8-2.2 Mg ha⁻¹), and the highest variability (CV = 56%). Seed quality of safflower and crambe remained stable throughout the study, with oil contents of 35% (CV of 2%) and 34% (CV of 1%), respectively, and consistent fatty acid composition with 78% of oleic acid and 55% of erucic acid content, respectively. In contrast, hemp biomass quality declined over time, as indicated by progressively heavier stems (from 12 to 30 g plant⁻¹), suggesting enhanced secondary growth and a consequent reduction in fiber quality. Miscanthus establishment was strongly affected by adverse weather conditions and weed competition in 2023. Above-ground biomass yield remained low in 2024 (2.4

Mg ha⁻¹) but increased in 2025 (5.0 Mg ha⁻¹), suggesting a transition to the productive phase. The results indicate that wide-strip intercropping managed under low-input rainfed conditions may represent a viable strategy for increasing spatial diversification while producing biomass on marginal land. Hemp and crambe showed the highest and similar adaptability, followed by safflower. Miscanthus performance was strongly influenced by establishment constraints, but biomass production more than doubled between 2024 and 2025, indicating promising productive potential that should be confirmed through longer-term observations.

Permanent Living Mulches is a Cornerstone for Integrating Organic and Conservative Agriculture in Mediterranean Vegetable Systems

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Session: 3. RI-PROGETTAZIONE

Presentation: Oral

The integration of conservation agriculture practices into organic vegetable systems is limited by the need to control weeds without herbicides while reducing reliance on intensive tillage and soil disturbance. Permanent living mulches (pLMs) represent an agroecological solution by providing continuous soil cover, limiting weed establishment and supporting low-disturbance soil management. In vegetable rotations, legume-based pLMs are expected to establish a dense sward in the inter-row space throughout successive crop cycles, contributing to soil protection, avoiding nutrient leaching, supporting biodiversity enhancement and weed control. This study evaluated the performance of legume-based pLM mixtures within an organic vegetable rotation, focusing on pLMs persistence, weed suppression, weed community dynamics and crop yield. A three-year field experiment was conducted under Mediterranean conditions in certified organic fields at the Center for Agri-Environmental Research "Enrico Avanzi", San Piero a Grado, Pisa, Italy. Permanent living mulches were established using mixtures of perennial legumes (*Trifolium repens* and *Lotus corniculatus*) combined with self-reseeding legumes (*Trifolium subterraneum* and *Medicago polymorpha*), selected to exploit complementary growth cycles and improve soil cover persistence over time. The system was tested in a vegetable rotation including broccoli, aubergine, fennel and tomato. Vegetable crops were transplanted into the pLMs using strip tillage, without fertilizer application. Two control treatments followed standard organic management, including standard soil tillage and fertilization and either inter-row weeding only (CNT2) or both inter- and intra-row weeding (CNT3). Mulch biomass, weed biomass, weed community composition and vegetable yields were assessed throughout the experiment. Permanent living mulches effectively suppressed weeds during the first two years of the rotation. The inclusion of self-reseeding species increased total pLM biomass and positively contributed to weed control, which was strongly dependent on pLM biomass production. However, pLM biomass progressively declined over time, while weed biomass increased, reducing the agronomic effectiveness of the system during the later stages of the rotation. Broccoli and aubergine marketable yields under pLM management were comparable to those obtained under standard organic management in CNT3, respectively $0.58 \text{ Mg ha}^{-1} \text{ DW}$ and $1.86 \text{ Mg ha}^{-1} \text{ DW}$, whereas

tomato marketable yield was substantially reduced, averaging $0.40 \text{ Mg ha}^{-1} \text{ DW}$ under pLMs compared with $2.40 \text{ Mg ha}^{-1} \text{ DW}$ in CNT3. The establishment of pLMs also produced a clear filtering effect on weed communities: *Polygonum aviculare* and *Kickxia elatine* decreased, whereas *Picris hieracioides* and *Lolium perenne* increased across successive crop cycles. Distinct weed communities developed between strip-tilled intra-rows, mainly dominated by annual species, and mowed inter-rows, where perennial species became more prevalent. Overall, pLMs showed strong potential as a functional bridge between organic farming and conservation agriculture in vegetable systems. Nevertheless, maintaining their long-term effectiveness may require adaptive management, including periodic tillage or mulch renewal strategies, to restore mulch competitiveness and rebalance weed community composition.

Assessing ecosystem services through agroecological practices: a multi-level approach across European Agroecological Living Labs

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Abstract ID: 258

Session: 3. RI-PROGETTAZIONE

Presentation: Oral

Agroecological transitions require robust, participatory methods to assess both the practices adopted and the ecosystem services these practices generate. This contribution presents the results of an assessment based on the involvement of 11 agroecological Living Labs (ALLs) participating in the European project ALL-Facts, with the aim of evaluating the contribution of agroecological practices to the provision of ecosystem services. The assessment draws on the APES Framework (Assessment of Practices and Ecosystem Services), developed within the European Horizon 2020 project RADIANT. The APES Framework can be used as a self-assessment tool by farmers or applied to farms by researchers, policymakers, or other interested parties. It links agricultural practices, more specifically agroecological ones, to the provisioning, regulating, and supporting ecosystem services they may generate. The framework comprises 16 ecosystem service indicators, including 8 provisioning services (for example, food, feed, fibre, energy, and genetic resources) and 16 regulating and supporting services (for example, carbon sequestration, nutrient cycling, pest regulation, and biodiversity). The framework was applied to selected farms in each of the 11 ALLs of the ALL-Facts project to assess the agroecological practices adopted at farm level and the provision of ecosystem services. The results offer both methodological insights for the assessment of ecosystem services and practical guidance to support a wider diffusion of agroecological practices across diverse European agricultural contexts.

Establishing soil organic carbon baseline for agricultural soils in Mediterranean area

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Session: 3. RI-PROGETTAZIONE

Presentation: Oral

Soil organic carbon (SOC) sequestration is a key strategy for improving the sustainability of agricultural systems and mitigating climate change. The effectiveness of carbon farming initiatives depends on the ability to estimate the maximum SOC storage capacity attainable under specific soil and climatic conditions. This study presents a multi-method framework to assess SOC storage capacity in Mediterranean agricultural soils across Spain, Italy, Slovenia and Greece. The approach assumes that permanent grasslands represent a realistic upper benchmark for SOC accumulation within a given pedoclimatic context. However, an analysis of SOC dynamics between 2009 and 2018 showed that more than half of the permanent grassland sites experienced SOC losses, suggesting that observed grassland stocks may provide conservative estimates of the actual SOC storage capacity. Harmonized data from the LUCAS Soil surveys (2009–2018) were integrated with climatic and remotely sensed productivity variables. Three independent methodologies were compared: (i) Gaussian Mixture Model (GMM) clustering to identify homogeneous pedoclimatic zones and derive grassland-based SOC benchmarks; (ii) an eXtreme Gradient Boosting (XGBoost) model trained on permanent grasslands to predict potential SOC stocks in agricultural soils; and (iii) the RothC soil carbon model coupled with Markov Chain Monte Carlo (MCMC) calibration to simulate long-term SOC dynamics and equilibrium stocks. The three approaches converged in identifying substantial SOC accumulation potential across Mediterranean arable systems. RothC simulations projected positive SOC increases in all pedoclimatic clusters, with gains ranging from 2.4 to 26.3 Mg C ha⁻¹ and a mean increase of 12.8 Mg C ha⁻¹. XGBoost predictions likewise highlighted significant gaps between current and potential SOC stocks, particularly in Italian croplands and orchards. The proposed framework provides a transparent and spatially explicit basis for defining SOC benchmarks and supporting carbon farming schemes and carbon credits payments.

Reviewing the state of the art of intercropping research in Italy

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Presentation: Pitch

Intercropping has gained renewed traction in developed countries due to its documented abilities to stabilize yields, reduce pest pressure and support soil health. Recently, research on intercropping has increased exponentially, focusing on empirical studies which investigate the best possible combinations and arrangements to limit the trade-off between agroecosystem services and yield. Several meta-analyses concluded that intercropping often results in win-win situations, but most of the available data come from temperate and tropical climates, which are less impacted by climate change compared to Mediterranean areas. In the context of EU policies oriented towards reducing pesticides by 50% by 2030 and accelerated climate change consequences, successful agroecological practices need to be rapidly identified and implemented at the local level. We performed a systematic review to point the lens at Italian research on intercropping. This approach allowed us to identify main knowledge gaps, research trends and methodological issues related to intercropping research in Italy, with a focus on arable crops for food and feed. We read 63 peer-reviewed papers to retrieve information on – but not limited to – the location, scale, species, arrangement, and outcome of intercropping trials. Overall, intercropping was investigated across the country, except for the Northwest (Piedmont, Liguria, Valle d'Aosta). Some regions were hotspots for research on the topic (e.g., Tuscany with n=19 published papers), while in others scientific interest faded before the end of the last century. A total of 61 species were used in the intercropping studies, mainly small-grain cereals and service legumes (e.g., clover and medic species) (Fig. 1). The main ecosystem services investigated were provisioning (increase in overall biomass/grain yield or nutritional quality, n=38 papers), regulating (weed control and nutrient cycling, n=21) and supporting (soil microorganisms, n=18). Even though the outcome was generally positive (in terms of yield losses and services delivered), most of the trials were performed in small-scale plot conditions with an average duration

of less than 2 years, with only two papers including an on-farm trial. Moreover, few papers provided data related to gross margin or cost-benefit analyses and limitations regarding seeding machinery or post-harvest separation were often overlooked. Our findings generally align with global meta-analyses, with most of the intercropped systems involving cereals and legumes, the latter often as a service crop. The main research trends identified were intercropping for food production, including vegetables, although feed and energy crops remained dominant. The main limitation pertained to the scale of experimentation, which only partially captures the complexity of Italian farms: stronger interdisciplinary collaborations are needed to include considerations like seed separation post-harvest, simple economic balances, market opportunities and policy development. Furthermore, the performance of intercropping needs to be considered within rotations to obtain a system's performance view, and properly transfer the knowledge to farmers and advisors. With this respect, farmers should play a primary role in co-designing intercropping systems, to increase the adoption of this diversification practice in their territory.

Glasswort (*Salicornia* spp.) as a strategic cropping system for promoting a new product value chain, preserving wetland ecosystems and restoring natural coastal areas

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Presentation: Pitch

Salicornia is a highly salt-tolerant halophyte and a promising frontier for climate-smart agriculture. Using seawater or brackish water for irrigation bypasses the traditional constraints of agriculture caused by a lack of fresh water and soil salinization, and addresses both climate mitigation and adaptation. The EU's legally binding Nature Restoration Law (NRL) broadens the scope of *Salicornia*, viewing it not only as a commercial alternative crop, but also as a dual purpose ecological and agricultural asset. The NRL's focus on coastal wetlands, salt marshes, and rewetted agricultural land helps balance conservation with economic viability. Effectively utilizing *Salicornia* requires a multi-tiered approach integrating agronomy, circular economy, and ecological restoration. Approach. Paludiculture: the NRL mandates for restoring and re-wetting drained agricultural wetlands. While taking this land completely out of production faces heavy resistance from the agricultural sector, *Salicornia* can provide a solution. Farmers can intentionally rewet coastal lowlands or degraded soils and make a transition to *Salicornia* cultivation. This approach keeps the land profitable while restoring the functions of the wetland ecosystem. Agronomic optimization: unlike traditional crops (glycophytes) that suffer osmotic stress from low salinity, *Salicornia* requires salt to thrive. Scaling the system demands strict resource management regarding tidal flooding, soil salinity, seawater/brackish water irrigation, and substantial irrigation depths to avoid salt crusting. Local species and ecotypes should be chosen to leverage their adaptability and phenotypic plasticity. Biodiversity and multi-species co-design: to avoid violating the NRL's strict biodiversity indicators against monoculture farming, polyculture systems are utilized by intercropping *Salicornia* with other native halophytes and conventional vegetables. Considering salt marshes are vital feeding and nesting grounds for migratory waterfowl and shorebirds, danger cultivation practices and mechanical schedules must strictly avoid spring nesting seasons to support EU bird abundance indices. Land reclamation and ecological co-benefits: *Salicornia* serves as a biological remedy for damaged landscapes through phytoremediation of marginal lands, abandoned due to secondary salinization. It stores salt within its succulent tissues, reducing net soil salinity. Wetland plantations can also generate monetizable "blue carbon credits" because their extensive root systems trap

sediment and are highly effective at long-term carbon burial. Cultivation should be placed in buffer zones or transitional lands adjacent to untouched core sanctuaries, where it acts as a biofilter that captures agricultural runoff before it causes water eutrophication. Value-chain diversification: for farmer adoption, the crop must be financially self-sustaining. *Salicornia* offers multiple commercial streams, notably the gourmet food market where its tender green tips are prized as a top-quality vegetable. Other options include alternative food preparations (in brine or oil, as a cream, etc.) and products, like functional "green salt". Past projects, like PNRR Agritech, PRA and future proposals, like PRIN Halo-Veg, investigate on these diverse issues, particularly focusing on wetlands of the Gargano area (FG), where local farmers have long shown interest. *Salicornia*, one of the most successful examples of halophyte cultivation, is proposed as a pilot system to showcase nature-based solutions and the best agroecological practices for restoring marginal coastal wetlands of high ecological value.

A multi-sensor open-field crop dataset for yield and quality monitoring in agrivoltaic systems

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Presentation: Pitch

In recent years, agrivoltaic (AV) systems have gained widespread adoption worldwide, emerging as a key sustainable solution for mitigating climate change by integrating renewable energy production with crop cultivation on the same land. However, the partial shading and microclimatic modifications induced by photovoltaic modules require a deeper understanding of crop physiological responses to optimize agronomic management under open-field conditions. Therefore, a comprehensive monitoring framework is essential to effectively balance energy production and crop performance. A field experiment was conducted in 2025 within a single-axis tracker AV system on yellow melon (*Cucumis melo* L.) and processing tomato (*Solanum lycopersicum* L.) in Sicily, Italy. The aim of the study was to evaluate the implementation of an advanced proximal multi-sensor system and an environmental monitoring network within an AV facility. A combination of proximal sensing technologies and environmental probes was employed. The effects of two different plastic mulching films (black vs white) on the crops were also evaluated. We compared the main findings obtained within the AV area with those produced in open-field conditions. Crop nutritional status and photosynthetic capacity were assessed by measuring leaf chlorophyll content using a chlorophyll meter. Canopy vigor and spatial vegetation dynamics were monitored through the Normalized Difference Vegetation Index, derived from two complementary platforms: unmanned aerial vehicles equipped with high-resolution multispectral cameras and a portable active sensor. Crop water stress was evaluated by measuring leaf temperature with a portable infrared thermal camera. Simultaneously, the main climatic data were collected using an on-site weather station. In addition, below-ground dynamics were continuously monitored using capacitive soil sensors installed at a depth of 20 cm to measure volumetric soil water content and soil temperature. Vegetation indices showed the highest values in the shaded AV area. In contrast, plants grown under full open-field conditions exhibited a sub-optimal physiological status, primarily due to severe heat stress. These physiological advantages were reflected in crop productivity. For instance, average yield data for processing tomato revealed that the AV area achieved a marketable yield of 12.5 t ha⁻¹. Conversely, the open-field area recorded a lower marketable yield of 9.1 t ha⁻¹. Regarding yellow melon, the AV area produced a marketable yield of 12.3 t ha⁻¹, whereas the open-field area recorded a higher marketable yield of 13.4 t ha⁻¹. The results indicate that proximal sensors effectively capture the responses of processing tomato and yellow melon crops to the modified light and moisture regimes

characteristic of AV systems. The integration of climatic, soil, and physiological data streams has proven to be an indispensable tool for validating the overall sustainability of AV systems. The partial shading provided by the solar panels mitigated extreme summer stress, enabling crops grown under AV conditions to achieve yields comparable to, and in some cases higher than, those recorded in open-field conditions. This multi-sensor approach continues to provide actionable insights for precision agriculture, maximizing land-use efficiency and enhancing the resilience of open-field cropping systems.

Improving land-use efficiency through cereal-legume intercropping in Mediterranean organic vineyard-based agroforestry systems

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Presentation: Pitch

Agroforestry is a traditional Mediterranean practice regaining interest for its contribution to the sustainability and resilience of farming systems through ecosystem services supply, production diversification and improvement of socio-economic viability. This study aimed to determine the land equivalent ratio of barley, burr medic, and their intercrop in a Mediterranean organic vineyard-based agroforestry system, compared with their respective sole crops and sole vines. The field trial is ongoing in a 16-year-old organic vineyard of *Vitis vinifera* L. located in Rodì Milici (Messina, Italy, 38°06' N, 15°08' E, 100 m a.s.l.) on a red berried Nero d'Avola cultivar, during the 2025–2026 growing season. The experiment was set up in an agroforestry system combining vines with forage species and their mixture [*Hordeum vulgare* L. var. Tonic, *Medicago polymorpha* L. var. Scimitar] in the inter-rows, alongside the forage sole crops and the sole vines, in a randomized complete block design replicated three times. The soil was disc-harrowed in autumn at 20 cm depth, and the forage crops were manually sown. In May, when the species reached the flowering stage, dry biomass of forage and weeds was determined in 1 m² quadrats in each treatment and replicate. The Land Equivalent Ratio (LER) was calculated as the sum of the ratios between intercrop and sole crop yields of each species. The land saving (%) was calculated as $[1 - (1/\text{LER}) \times 100]$. Data were analyzed by a mixed-effect model and means separated by Tukey's HSD at $P \leq 0.05$. Cropping system and crop species significantly influenced forage dry biomass ($P < 0.001$ and $P = 0.011$, respectively), while their interaction was not significant. Sole cropping produced higher forage biomass than the agroforestry system, with barley and the barley-burr medic intercrop outperforming burr medic. In the agroforestry system, all forage species and their mixture significantly reduced weed pressure compared with sole vines. Overall, the barley-burr medic intercrop showed the best performance for both weed control (-96.7%) and forage dry biomass (5.74 Mg ha⁻¹). The barley-burr medic intercrop also improved the LER, either in the sole-cropping (1.07), and the agroforestry systems (1.17), corresponding to 6.9 and 14.8% land savings. The partial LER in the agroforestry was below 1 in both

barley and burr medic, but higher than 1 in the barley-burr medic intercrops. The vineyard agroforestry system resulted in lower individual crop yields than open-field conditions but substantially reduced weed pressure compared with the sole-vineyard. Nevertheless, the barley-burr medic intercrop enhanced land-use efficiency, achieving land savings of 6.9 and 14.8% under sole-cropping and agroforestry, respectively. In the agroforestry system, the partial LERs of both barley and burr medic were individually below 1, indicating lower yields than their respective sole crops. However, the combined partial LER exceeded 1, demonstrating a clear intercropping advantage over monoculture within the vineyard alley. The total LER, including the vine component, will be determined following grape harvest in September. Acknowledgements. Funded by PRIMA 2024 - Section 2. Topic 2.2.1. Project "SCALARE - SCaling Agroforestry by living LABs for Resilient Mediterranean agro-Ecosystems" (CUP: J43C25000480001).

Greenhouse gas emissions from a wheat–pea intercrop in arable and silvoarable systems under different nitrogen fertilization rates in Central Italy

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Presentation: Pitch

Modern agricultural systems are required to increase resource-use efficiency while reducing greenhouse gas (GHG) emissions associated with crop production. Among the agroecological approaches aimed at improving nitrogen (N) cycling, strengthening cropping system resilience, and reducing environmental impacts, intercropping (IC) and agroforestry play a central role. However, information on the combined effects of these practices on soil GHG emissions under rainfed Mediterranean conditions remains limited. Moreover, in these environments, N fertilization is often required also in intercropping to support the cereal's growth in N-poor soils. Our study aimed to evaluate the effects of nitrogen fertilization and cropping system on soil GHG emissions in a wheat (*Triticum aestivum* L.)–pea (*Pisum sativum* L.) intercropping. The open-field experiment was conducted at the Centre for Agri-environmental Research “E. Avanzi” (University of Pisa, Central Italy) over two consecutive growing seasons. Treatments consisted of two cropping systems, namely arable (AR) and silvoarable (SIAR), that is wheat-pea intercropping cultivated with or without poplar trees, respectively and two nitrogen fertilization rates (0, and 140 kg N ha⁻¹). The treatments were arranged in a randomized complete block design with three replications. Soil emissions of nitrous oxide (N₂O), carbon dioxide (CO₂), and methane (CH₄) were monitored throughout the crop cycle in spring-summer 2024 and 2025 using two 8200-01S LI-COR smart chambers configured with LI-7810 CH₄/CO₂/H₂O and LI-7820 NO₂/H₂O Trace Gas Analyzers (Figure 1). Measures were taken in the morning between 8 and 10 am on May 30, June 13, and July 26 in 2024 and on April 23, May 29, and June 10 in 2025. Gas fluxes were calculated using SoilFluxPro software and integrated over time to estimate cumulative seasonal emissions. A two-way ANOVA was performed separately for each year to assess the effects of cropping system, nitrogen rate, and their interaction. Nitrous oxide emissions were strongly influenced by nitrogen fertilization, with the highest fluxes occurring following fertilizer applications and rainfall events. Cumulative N₂O emissions increased with increasing N

rates, whereas differences between cropping systems were less pronounced. Methane fluxes remained close to neutral throughout the experimental period. Cumulative soil CO₂ emissions ranged from 1.8 to 3.2 Mg CO₂ ha⁻¹ during the monitoring period in the first year and from 1.6 to 2.7 Mg CO₂ ha⁻¹ in the second growing season (Figure 2), values consistent with those reported for Mediterranean agroecosystems under contrasting soil management and nitrogen fertilization regimes. Nitrogen fertilization increased CO₂ emissions in 2024, particularly in AR (+74%), whereas contrasting responses were observed in 2025, indicating a strong interaction between climatic conditions, nitrogen availability, and cropping system on soil carbon dynamics. These findings highlight the potential of combining intercropping and agroforestry as climate-smart strategies for Mediterranean agriculture. Optimized nitrogen management can improve the environmental sustainability of diversified cropping systems while maintaining productive performance. The research was carried out as part of the National Center for Technology in Agriculture (AGRITECH) and funded by the National Recovery and Resilience Plan (PNRR) of the European Union – MISSION 4 COMPONENT 2, INVESTMENT 1.4 – D.D. 1032 17/06/2022, CN00000022).

Dominance Vulnerability Index (DVI): a biodiversity index for early prediction of weed-induced yield losses

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Presentation: Pitch

The widespread adoption of monoculture and chemical weeding has reduced agroecosystems to mere production units, neglecting the broader ecosystem services that agriculture can offer to society. Current cropping systems often favor the proliferation of highly competitive weed species, leading to dominance phenomena. We propose that weed dominance represents the primary driver of weed-induced yield losses in winter wheat. Thus, restoring a more balanced weed community may be a promising strategy to preserve crop yields while enhancing biodiversity, ultimately maximizing the ecosystem services provided by agricultural systems. To achieve this goal we developed a biodiversity index (Dominance Vulnerability Index, DVI) to quantify, at early stage of weed infestation, critical areas in the field where weed distribution should be rebalanced by controlling weeds overgrowth. *Triticum aestivum* var. *Rebelde* was cultivated in Portici (NA) during the growing season 2022, and in Bellizzi (SA) during the growing seasons 2023 and 2025. Two treatments, namely weed-free and weedy, have been randomly assigned to different plots. At the tillering stage of wheat, weed density per species has been measured from arial pictures using a previously reported procedure. Based on weed density data, we calculated DVI as follows. For each plot, the relative abundance of each species (π_i) is calculated by considering the average weed density (AWD) of the field and compared to a theoretical equidistribution threshold (TET), calculated as 1 divided by the maximum number of species observed across the plots in the field. Only the species whose $\pi_i > \text{TET}$ are identified as dominant and contribute to the calculation of DVI. The number of individuals that exceed the threshold represents the number of weeds per species that must be removed to restore weed equal distribution. At the wheat heading stage, the biomass per weed species has been evaluated. Finally, wheat yield has been measured at maturity. The weed biomass and the yield from different sites and years were normalized and correlated with the different biodiversity indexes to calculate Pearson's r and the p -value. When comparing Pearson's r of different biodiversity indexes, we found that only dominance indices (Simpson's dominance index and Berger-parker index) correlated with yield percentage, while the equitability index (Shannon diversity index) did not show correlations. DVI shows high and significant correlation with total weed biomass at the heading stage of wheat ($r = 0.43$, $p\text{-value} < 0.001$), and with wheat yield percentage ($r = -0.71$, $p\text{-value} < 0.001$). Moreover, DVI allowed the identification of the dominant species, and the amount to be removed to

maximize the equitability of the production. Our results show that dominance, more than equitability, better describes the negative effects of weeds on wheat yield. A newly developed Dominance Vulnerability Index (DVI), that efficiently interpret the effects of weed dominance, can be useful to guide weeder robots to remove only dominant weeds, while leaving non-competitive species in the field.

What about shifting from conventional to organic farming in intensive olive orchards? An assessment on olive fruit fly pressure and insecticides treatments

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Session: 3. RI-PROGETTAZIONE

Presentation: Poster

Since ancient times the Mediterranean Basin represents the major olive cultivated area in the world, enough to be considered the cradle of olive domestication and expansion. Thanks to its suitability for low-fertility soils and drought-affected areas, olive tree is recognized as a crucial fruit crop in the Mediterranean Basin and it strongly characterizes the landscape as well as nutritional, cultural, and historical aspects of this region from antiquity up to present times. Although in the recent past the majority of the Mediterranean olive orchards were grown under low density and rainfed conditions, there is currently a shift toward intensive and super-intensive planting systems mainly because of the lack of manpower and unsustainable management costs. Furthermore, the ever-increasing interest in environmental issues has led EU countries to introduce regulations related to organic farming. These management transitions will probably exacerbate olive fruit fly (*Bactrocera oleae* (Rossi)) pressure on olive yield. The aim of the study was to evaluate the impact of switching from conventional to organic olive fruit fly control in intensive olive orchards under climate scenarios. A spatially distributed analysis was carried out in the Mediterranean Basin which is considered a climate change hotspot. Climate data were retrieved from the global high resolution Multi Source Weather (MSWX) database, while information on soil properties was found on the FAO Harmonized World Soil Database. For the olive tree crop mask, the CORINE Land Cover database and GAEZ FAO data portal have been used. To handle the uncertainty in future climate projections, two different General Circulation Models (IPSL-CM6A-LR and MPI-ESM1-2-LR) coupled with two Shared Socioeconomic Pathways (SSP2-4.5 and SSP3-7.0) have been considered for two timeframes centred on 2040 and 2060. Olive tree-olive fruit fly interaction, considering also fly predators, was simulated using a new modelling approach. Among model outputs, the percentage of infected olives and the number of insecticides treatments were analyzed as they are of fundamental importance to assess the environmental impact of olive tree-olive fruit fly interaction under different climate and management scenarios. Results showed that, at country level, olive fruit fly will have a higher pressure on olive yield under organic farming compared to the conventional one in almost all countries. Dynamic simulation of pesticides applications to contain fly population allowed also to estimate the environmental impact of alternative management scenarios, and to evaluate changes in the suitability of different areas for olive cultivation in the mid-term. This study highlighted the importance of analyzing the integrated impact of climate, management and regulatory scenarios on

the interactions between cultivated and wild species, and provided insight into long-term effects of different cultivation systems.

Optimizing Water Resources use and Yield Stability in Mediterranean Cotton cropping systems: A Regenerative Agriculture Approach

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Abstract ID: 172

Session: 3. RI-PROGETTAZIONE

Presentation: Poster

Southern Italy offers the ideal environment for cotton, yet its production must face the critical constraint of water scarcity while transitioning toward sustainable and regenerative models. This study evaluates the agronomic effects of regenerative agriculture practices applied to cotton in Southern Italy, assessing whether transitioning to low-impact systems can balance yield stability and water savings under different soil management strategies. The field trials were conducted during the 2024 and 2025 seasons in experimental fields of CREA in Rutigliano (BA), on a clay-loam soil (Luvisol/Vertic Cambisol) with a low organic matter content. The typical Mediterranean climate of the area is characterized by hot, dry summers, which were monitored via an on-site weather station to compute soil water balance. The effects of (i) two irrigation water regimes [full irrigation (I100, 100% ET) and deficit irrigation (I50, 50% ET), started one month after sowing], (ii) three soil management [conventional tillage (CT, plowing at 30 cm and hoeing), minimum tillage (MT, within 10–15 cm, preceded by a vetch cover crop), and no-tillage (NT, direct seeding, preceded by a vetch cover crop)] and (iii) three genotypes [ST402, Armonia, and Hybrid HA1432, to evaluate their specific adaptability to regenerative protocols] were evaluated under the field trials. The factorial

experiment was arranged in a split-split plot experimental design with three replicates, considering irrigation water regime as main plot factor, soil management as sub-plot factor and variety as sub-sub plot factor. Soil water content (SWC) was continuously monitored using capacitive probes (at depths of 0.2 and 0.4 m) connected to GPRS dataloggers. Seasonal water consumption amounted to 352 mm for I100 and 222 mm for I50 in the 2024 season, and 322mm for I100 and 205 mm for I50 in 2025, highlighting the water savings achieved through the deficit irrigation strategy. SWC showed that the CT under the I50 regime frequently dropped below the readily available water threshold. This indicated water stress in both years compared to the alternative soil management systems, establishing the basis for higher water use efficiency. In the 2024 season, the highest yields were recorded under MT, (2.89 t/ha) and, among genotypes, by the hybrid HA1432 (2.99 t/ha). In addition, under deficit I50, the MT strategy resulted in significantly higher production, whereas no differences emerged among soil management systems under the I100 regime. During the 2025 season, crop yield and WUE were significantly affected by the interaction among irrigation, soil management, and genotype. Interestingly, the varietal choice produced a significant difference only under I100 combined with NT. In this scenario, the hybrid HA1432 outperformed the others, reaching the highest yield (5.60 t/ha) and the best WUE. Under I50 or in tilled plots (CT and MT), no statistical differences were observed among the genotypes, which showed comparable yield stability and water efficiency. In conclusion, combining regenerative soil management (particularly MT) with rational irrigation optimizes water resources use, alleviates stress within the soil-plant system, and stabilizes crop yields, confirming the sustainability of this supply chain in Mediterranean environments.

Effects of varietal mixtures on yield performance and functional complementarity in chickpea (*Cicer arietinum* L.)

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Session: 3. RI-PROGETTAZIONE

Presentation: Poster

Chickpea (*Cicer arietinum* L.) is a key legume in the plant-based protein market, with Italy ranking among the leading European producers. However, climate change is increasingly intensifying both biotic and abiotic stresses affecting the crop, particularly drought and soil-borne pathogens such as *Fusarium oxysporum* f. sp. *ciceris* (Foc) and *Ascochyta rabiei*, which can cause severe yield losses ranging from 10% to 70%. In this context, the deployment of agrobiodiversity through cultivar mixtures represents a promising strategy. The co-cultivation of multiple genotypes with diverse and complementary functional traits, if properly selected and chosen, can enhance yield stability, improve resource-use efficiency, and potentially reduce disease spread due to differential host susceptibility, thereby lowering pesticide dependence and supporting more sustainable production systems. The present work aims to evaluate whether varietal mixtures can improve yield performance and stability compared with single-stand cultivation. In particular, the study investigates the effects of intra-specific genetic diversification on crop productivity, focusing not only on varietal richness (number of genotypes) but also on the functional complementarity among traits. To address these objectives, a field experiment was conducted in Pisa (Italy) using a randomized complete block design with three replications (147 plots). A total of 49 chickpea varietal mixtures were evaluated, ranging from 2 to 16 varieties per mixture. These combinations were structured around four core four-variety pools designed to represent contrasting functional strategies: growth habit divergence (Mix A), stress complementarity (Mix B), *Fusarium* tolerance redundancy (Mix C), and drought tolerance redundancy (Mix D). The trial was sown under rainfed conditions in April at a density of 40 seeds m⁻². Throughout the growing season, plant height, canopy cover (assessed via drone imagery), severity of *Ascochyta rabiei*, and weed biomass were monitored. At maturity, total biomass and yield components were quantified through quadrat sampling (80 × 50 cm), with individual cultivar contributions separated manually based on seed coat color. Since this represents the first year of field experimentation, only preliminary results regarding yield stability can be reported. Nevertheless, several varietal mixtures exhibited higher yield per unit area compared with most of their parental varieties grown in single stand conditions. The magnitude of yield divergence between pure stands and mixtures varied among genotypes, indicating differential responses to intergenotypic competition. Notably, some varieties were less affected by co-cultivation and contributed disproportionately to total mixture yield, suggesting potential effects of functional complementarity and differences in resource-use efficiency among genotypes. Taken together, these

preliminary results confirm the hypothesis that mixture performance is shaped not by the additive effects of yield potential of individual varieties but by the nature of their ecological interactions under co-cultivation.

Effect of biostimulant treatment on morpho-physiological traits and cone yield of four hop (*Humulus lupulus* L.) cultivars in a Mediterranean environment

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Session: 3. RI-PROGETTAZIONE

Presentation: Poster

The expansion of hop (*Humulus lupulus* L.) cultivation in the Mediterranean region offers valuable new opportunities for local supply chains. However, every geographical shift exposes crops to new biotic and abiotic stresses that can not be faced in the same way as the traditional growing areas. To address this critical issue, field studies are required to understand the complex interaction among hop genotype, environment and agronomic practices. With this aim, a field experiment was set-up to study the effect of biostimulant application on morpho-physiological traits and cone yield of different commercial hop cultivars under Mediterranean climatic conditions. The study was conducted at the experimental farm of the University of Tuscia, Viterbo (300 m a.s.l.), Italy, on typical volcanic soil. Four hop varieties were used in this experiment, namely Alberich, Cascade, Gimli, and Nugget. Hop plants were planted during autumn 2023 in a 7-meter-high vertical "V-trellis" hopyard. A drip fertigation system was used to water and fertilize the crop when needed. A split-plot experimental design with three replicates was used to assess the effect of genotype, biostimulant application and their interaction on crop performance. Pathogens and pests were controlled when necessary, using orange essential oils, zeolite, and copper. Extracts of the seaweed *Codium fragile* (Suringar) Hariot and Indian fig opuntia (*Opuntia ficus-indica* (L.) Mill.) were used as foliar biostimulants and applied four times from late June to late July. Cone harvesting was performed from August to September, according to cultivar maturity timelines. Cones were oven-dried until they reached commercial moisture. Recorded variables included chlorophyll content, fresh and dry matter of plants, cone dimensions and yield. Statistical analyses revealed that biostimulant treatment never influenced hop performance, while genotype significantly affected most of the measured traits. Alberich and Cascade maintained a constant chlorophyll content (≥ 35 SPAD units) during all the growing season, while Gimli and Nugget exhibited marked drops in July and August. Despite this, Nugget showed the highest fresh and dry cone weight (0.7 g and 0.18 g, respectively), followed by Cascade (0.5 g and 0.12 g, respectively), Gimli and Alberich (both with 0.3 g and 0.07 g, fresh and dry weight). As expected, Nugget and Cascade produced greater shoot biomass and longer cones than the dwarf cultivars Alberich and Gimli. Genotype $\times$ treatment interaction significantly affected cone diameter. Particularly, biostimulant application increased cone width by 30% in cultivar Nugget. Regarding cone yield, Cascade and Nugget performed similarly (0.4 t ha⁻¹), showing a remarkable difference as compared with dwarf varieties, which both achieved 0.1 t ha⁻¹. Collected field data showed that, during the first production season (second year of plantation) cone yield and plant development

were driven almost entirely by genotype rather than biostimulant application. As compared with dwarf varieties, Cascade and Nugget demonstrated superior agronomic performances under field conditions of a Mediterranean environment. Additional field data from mature plants are needed to fully understand the potential of biostimulant treatment on hop agronomic performance.

Bioagronomic Performance of Legume and Grass Cover Crops in a Mediterranean Vineyard

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Session: 3. RI-PROGETTAZIONE

Presentation: Poster

Cover crops (CCs) represent one of the main agroecological strategies for enhancing the sustainability of Mediterranean vineyard systems, contributing to improved soil fertility, reduced erosion processes, and increased functional biodiversity. However, the effectiveness of different species and their mixtures is strongly influenced by agroecosystem conditions, making site-specific experimental evaluations essential. This study evaluated the adaptability and agronomic performance of different cover crop systems in a Nero d'Avola vineyard located within an environment representative of Sicilian Mediterranean viticulture (Comiso, RG, Italy). The experiment was conducted over two consecutive growing seasons (2025 and 2026) using a randomized complete block design with three replications. Faba bean (*V. faba* L. minor) and barley (*H. vulgare* L.) were evaluated as sole crops and in two legume grass mixtures differing in species proportions (Mix 1: F–B–B–B–F; Mix 2: F–B–F–B–F). The CCs systems were tested under two vineyard topographic positions (upslope and downslope), in order to assess agroecosystem responses under different environmental conditions. CCs agronomic performance was assessed through measurements of emergence density, plant height, SPAD, photosystem II photochemical efficiency (Φ PSII – measured only in 2026), leaf area index (LAI), and dry biomass yield (DBY). To assess the effects of cover crop systems and topographic position on vineyard physiological status and performance, SPAD and Φ PSII were also measured on grapevine. The first results showed that faba bean emergence density was significantly affected ($p < 0.01$) by CCs treatments, whereas barley emergence density was significantly influenced ($p < 0.001$) by both growing season and CCs treatments. In both growing seasons, CCs treatments and topographic position significantly affected ($p < 0.01$) plant height in both faba bean and barley. In the mean of the CCs treatments, a significant difference ($p < 0.01$) was observed on DBY and LAI indicating a greater vegetative development under downslope location. From an ecophysiological perspective, faba bean SPAD values were significantly ($p < 0.001$) influenced by growing season, with higher chlorophyll content recorded in 2025 than in 2026. In contrast, barley SPAD values did not show significant seasonal variation. Moreover, no significant differences in Φ PSII were detected among CCs treatments. SPAD and Φ PSII values in grapevine leaves were significantly ($p < 0.01$) influenced by topographic position, with higher values observed in upslope than downslope plots, whereas no significant effects of CCs treatments were observed. The results demonstrate that both pure stands and mixed CCs systems are well adapted to Mediterranean vineyard conditions, showing satisfactory establishment and growth across contrasting topographic positions. Topography emerged as a key factor influencing CCs development and grapevine

physiological performance, likely through its effects on soil water availability and retention. While CCs composition affected some establishment and growth parameters, it did not negatively impact on grapevine physiological status. Overall, the findings support the adoption of both monoculture and mixed-species CCs as sustainable vineyard floor management strategies, capable of enhancing agroecosystem functionality without compromising grapevine performance. Further investigations will be useful to assess the long-term effects of these systems on soil quality, water dynamics, and vineyard productivity.

Changes in floristic composition of cover crop mixtures for autumn-winter grazing in the Po valley

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Session: 3. RI-PROGETTAZIONE

Presentation: Poster

Cover crops provide numerous agroecological benefits, including increased SOM, reduced erosion, improved soil structure, and weed suppression. In addition, they contribute to forage production and biodiversity conservation. For these reasons, multispecies mixtures are becoming increasingly widespread, as they provide a greater range of ecosystem services than monocultures through synergistic interactions among species and enhanced agroecosystem functioning. The study was conducted at the Experimental Farm of the University of Padua in Legnaro (north-eastern Italy; 45°20'N, 11°57'E; altitude 8 m) during autumn-winter 2026. The area is characterised by a mean annual temperature of 13.6°C (minimum 9.1°C; maximum 17.7°C) and a mean annual rainfall of 781.8 mm. The aim of the study was to assess changes in the floristic composition of 18 cover crop mixtures intended for grazing during the autumn-winter season. The mixtures were arranged in a three-replicate randomised complete block experimental design. The mixtures mainly consisted of *Hordeum vulgare* L., *Lolium multiflorum* Lam., *Lolium perenne* L., *Trifolium pratense* L., *Trifolium repens* L., and *Dactylis glomerata* L., sown in September 2026 with different species proportions in the seed mixture (Table 1). Botanical composition was monitored monthly from November to April using the vertical point-quadrat method along 2.4-m linear vegetation transects. Along each transect, at 12-cm intervals, plant species touching a steel needle were identified and recorded. For each survey, species relative abundance (SRA) was calculated and used to determine the proportions of individual species using a standard equation. For each species, an ANOVA was performed to assess whether there was a positive interaction between species abundance and time or among the different treatments. Changes in floristic composition among mixtures showed distinct patterns depending on the species considered. Across all mixtures, *Lolium multiflorum* maintained relatively stable abundance throughout the observation period, indicating greater persistence and competitiveness than the other species included in the mixtures. For *Trifolium pratense*, *Lolium perenne*, and *Dactylis glomerata*, a significant interaction was observed among species abundance, experimental treatments, and time. In particular, these species exhibited a satisfactory abundance during the autumn, followed by a progressive and steady decline throughout the winter period, reaching minimum values in April. This trend suggests a limited competitive ability, especially in mixtures with lower sowing proportions of these species and a higher proportion of *Lolium multiflorum*. In

contrast, *Trifolium repens* did not show substantial changes in abundance over time, but only among the different treatments, indicating greater compositional stability within the mixtures. Increasing the proportion of Fabaceae in the seed mixture composition increased their abundance, particularly at sowing proportions of 20% and 30%. Consequently, M5-80/20 and M3-80/20 mixtures exhibited higher stability in floristic composition, resulting in a more balanced proportion of Poaceae and Fabaceae and, potentially, higher forage quality.

Cereal-legume intercropping as a sustainable strategy to enhance primary production

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Presentation: Poster

Increasing the productivity of low-input cropping systems is one of the main challenges for Mediterranean agriculture, especially where high biomass production is required without increasing the use of external inputs. Cereal-legume intercropping may offer a practical way to address this challenge, by combining the high yield potential of cereals with the ecological functions of legumes. In this study, biomass sorghum (*Sorghum bicolor* L.) was intercropped with two tropical legumes, sunn hemp (*Crotalaria juncea* L.) and pigeon pea (*Cajanus cajan* L.), and the systems were evaluated with and without the application of a PGPR-based biostimulant. The field trial was carried out in Bologna, Northern Italy, during the 2025 growing season. The experiment included three monocrops (biomass sorghum, sunn hemp and pigeon pea) and two cereal-legume intercrops (sorghum + sunn hemp and sorghum + pigeon pea). Each cropping system was tested with and without the application of PGPR biostimulant containing *Bacillus* sp. VWC18. Treatments were arranged in a randomized complete block design with four replications. During the crops cycle, biometric and physiological traits were monitored, including plant height, stem diameter, branching, chlorophyll content and photosynthetic efficiency. Aboveground biomass was measured at flowering and at maturity, separating the contribution of each species in the intercropping systems. Intercropping increased total aboveground biomass compared with sole sorghum. At flowering, the sorghum + sunn hemp system produced about 26% more biomass than sorghum monocropping, while the sorghum + pigeon pea system showed the strongest response when combined with PGPR application, reaching an increase of up to 44% compared with sole sorghum. A similar pattern was observed at maturity, where both intercropping systems maintained a clear productive advantage. Total biomass increased by about 35% in sorghum + sunn hemp and by 57% in sorghum + pigeon pea compared with sorghum monocropping. These results suggest that the legume component contributed additional biomass without reducing the productive role of sorghum within the system. The Land Equivalent Ratio (LER) provided additional insight into the functioning of the intercropping systems. Partial LER values showed that the contribution of sorghum and legumes varied depending on the associated species and PGPR application. At flowering, the highest total LER was observed in the sorghum + pigeon pea system under PGPR treatment, where both crop components contributed substantially to the overall advantage. In the sorghum + sunn hemp system, the increase in LER was mainly driven

by the sorghum component. At maturity, total LER remained above 1 in all intercropping systems, but the effect of PGPR was no longer statistically significant. Overall, the results show that sorghum-based intercropping with tropical legumes can increase biomass production and land-use efficiency under Mediterranean field conditions. This approach may therefore represent a useful option for developing more diversified and resource-efficient cropping systems.

Living Labs and co-creation for the adoption of validated, field-applicable agroecological practices in Mediterranean cereal systems: the AgrEcoMed, CoolFarmLab and CropRotaM trajectory

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Presentation: Poster

Since 2022, a coordinated sequence of projects, AgrEcoMed, CropRotaM (PRIMA) and CoolFarmLab (Agroecology Partnership), have applied a co-creation approach based on Living Labs. Continuity across the projects allows the results of each to feed the next, and makes farmers and supply-chain operators protagonists of the redesign, validation and on-farm transfer of practices. This work compares field agronomic evidence with the diagnosis voiced by the actors. Here, agroecological innovation is defined as a practice grounded on agroecological principles, validated by agronomic, environmental and economic results measured in the field and adoptable under real farm conditions. The Living Lab at the La Generale cooperative farm in Genzano di Lucania (Potenza), within AgrEcoMed and CoolFarmLab, shows that participatory redesign delivers concrete results: the agroecological system co-designed with farmers (diversified rotation, low-impact tillage, variable-rate fertilization, legume-based nitrogen, and temporal, spatial and genetic diversification) outperformed the conventional durum wheat monosuccession, with higher yield (+14.9%), lower nitrogen inputs (-34%) and more than doubled eco-efficiency. Over four years, however, the agronomic result is only part of the picture. The core of the work is the participatory diagnosis. The multi-actor Living Labs made the actors central to the adoption analysis and showed that transferability depends on enabling conditions more than on technique. Farm fragmentation is the main obstacle, and aggregation among farms is the “necessary condition” to overcome it; the actors observed that “the mere availability of innovations is not sufficient unless accompanied by real and continuous support to farms during the adoption phase” and identified the most effective solutions in “integrated management packages” rather than in “isolated techniques”. Priorities for direct transfer are therefore aggregation, technical equipment, training of operators and contractors, and supply-chain organization, which CropRotaM addresses in the farm-level upscaling of rotations and biodiversity through digital technologies. The value of the approach lies in the Living Lab model and in the continuity across projects, which turn supply-chain actors into vehicles of technology transfer in fragmented Mediterranean areas. The next phase will validate integrated, co-designed packages in

the field, with a defined operational outcome: the submission of an application under the regional Rural Development Complement (CSR).

From Soil Health to Carbon Credit: A Blockchain-IoT Framework for Climate Smart Agriculture

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Session: 3. RI-PROGETTAZIONE

Presentation: Poster

Agriculture plays a critical role in climate change mitigation through its capacity to enhance soil carbon sequestration and reduce greenhouse gas emissions. However, the implementation of carbon farming and agricultural carbon credit schemes remains constrained by challenges related to monitoring, reporting, verification and transparency of soil and crop management data. Recent advances in digital agriculture technologies offer new opportunities to address these limitations while supporting sustainable and climate smart farming systems. This study presents a conceptual framework that integrates soil plant monitoring, Internet of Things (IoT) technologies, blockchain infrastructure, artificial intelligence (AI) and smart agriculture tools to support transparent and verifiable carbon crediting in agricultural systems. The framework builds upon previous research involving blockchain enabled agricultural traceability, decentralized applications for farming systems and climate smart agriculture solutions that combine sensor networks, data analytics and distributed ledger technologies. Within the proposed framework, IoT devices continuously collect field level information on soil moisture, temperature, salinity, nutrient availability, soil organic carbon and environmental conditions, while crop monitoring technologies provide data on plant growth, biomass accumulation, productivity and resource use efficiency. These datasets are integrated into a blockchain based platform that enables secure, immutable and transparent recording of agricultural activities and environmental indicators. Smart contracts can facilitate automated verification processes and improve trust among farmers, certifying bodies, carbon market participants and policymakers. The integration of real time soil and crop data with blockchain technology has the potential to strengthen monitoring, reporting and verification (MRV) systems required for agricultural carbon credit programs. By providing reliable evidence of management practices and environmental outcomes, the framework can support the quantification of carbon sequestration, promote adoption of regenerative agricultural practices and reduce uncertainties associated with carbon accounting. Furthermore, the approach can improve transparency across agricultural value chains while encouraging sustainable land management, efficient resource utilization and climate resilience. Beyond carbon markets, the framework offers opportunities for advancing precision agriculture through data driven decision making and enhanced understanding of soil plant interactions. The proposed system promotes interoperability among farmers, researchers, regulators and carbon credit stakeholders, enabling more effective assessment of sustainability indicators and environmental performance. The integration of blockchain, IoT, AI and soil plant monitoring technologies represents a promising pathway toward scalable and transparent

carbon farming systems capable of supporting sustainable agricultural development, improving soil health and contributing to global climate mitigation goals.

Agronomic research to mitigate the effects of climate change on ancient wheats: the Svernalfar! project

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Session: 3. RI-PROGETTAZIONE

Presentation: Poster

In inland areas, low-intensity farms frequently rely on niche crops instead of commodities, and organic cultivation practices are commonly adopted. Einkorn (*Triticum monococcum* L.) and emmer (*Triticum turgidum* subsp. *dicoccum* Schrank ex Schübl.) play an important role within cropping systems of marginal areas. These ancient cereals, traditionally cultivated in inland zones of Tuscany, are characterized by a strict requirement in terms of vernalization. Unlike modern wheat cultivars, these locally adapted genotypes have undergone to limited genetic improvement, usually retaining a strong dependence on winter cold exposure for the transition from vegetative to reproductive phase. This aspect, within climate change context, is recognized by farmers as a critical aspect. This because the progressive increase of temperatures and the occurrence of milder winters often lead to insufficient cold exposure, negatively affecting flowering induction and, consequently, reducing grain yield and productivity stability. Withing the SvernalFAR! project, funded by EIP-AGRI Operational Groups (EU Regulation 2021/2115), a collaborative initiative has been established among farmers, researchers, and advisors. This project aims to assess agronomic practices designed to enhance the quality and vigour of emerged seedlings across diverse lines of einkorn and emmer wheat, mitigating the adverse impacts of climate change and addressing the needs of local farmers. Experimental activities will encompass multi-scale trials, ranging from laboratory to real-farm level. The primary research axis focuses on evaluating seed treatments, specifically artificial vernalization (chilling treatments) and seed inoculation with microbial consortia. Seed pre-chilling aims to satisfy cold requirements during the pre-sowing phase, thereby fostering accelerated and more uniform plant development. Furthermore, arbuscular mycorrhizal fungi and plant growth-promoting rhizobacteria inoculation aims to enhance plant growth, optimize nutrient uptake, and improve tolerance to abiotic stresses. The integration of these approaches may promote more uniform germination, faster emergence, and greater vigour during early stages of crop establishment. This activity is conducted both at laboratory level, to identify the best treatment combinations, and on real-farm conditions (Pieve a Salti and Podere Pereto), to validate the agronomic transferability. In parallel, the project includes a varietal screening, involving four einkorn and seven emmer varieties, assessing both commercial cultivars, and populations maintained by farmer partners in the Svernalfar! This activity aims to evaluate the cold requirements of both farmer-grown materials and currently available commercial germplasm and to identify the most suitable genotype for Tuscany pedoclimatic conditions. Moreover, multi-location trials are also conducted in different sites across Tuscany

(Buonconvento and Rapolano Terme, SI; Santa Luce, PI; Vada, LI) to assess genotype responses to different pedoclimatic conditions and cropping systems (organic and integrated agriculture). Crop monitoring and destructive and non-destructive samplings are scheduled during crop development and plant maturity to assess crop adaptability and productivity. A further activity involves genetic and proteomic characterization of einkorn and emmer populations to support quality certification, molecular traceability, and the valorisation of local products along the entire supply chain. The project implemented an interactive approach in the development of knowledge within farming communities, promoting innovative and transferable solutions in adapting to climate change, while promoting more resilient and sustainable production systems.

Agronomic feasibility of carinata-chickpea intercropping in Northern Italy

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Abstract ID: 227

Session: 3. RI-PROGETTAZIONE

Presentation: Poster

Intercropping oilseed and legume crops has been proposed as a strategy to diversify cropping systems and facilitate the integration of industrial crops into food-based rotations. While the interest in *Brassica carinata* (A. Braun) as a promising feedstock for Sustainable Aviation Fuel (SAF) continues to increase, its agronomic potential and integration into European cropping systems are being evaluated within the European CARINA project. In this context, this study provides the first assessment of a carinata-chickpea intercropping system under the pedoclimatic conditions of northern Italy, with the aim of evaluating its agronomic performance. A field trial was conducted at the Experimental Farm of the University of Bologna over two growing seasons (2023-24 and 2024-25). Carinata (cv. Nujet350, Nufarm, Canada) and chickpea (cv. Sultano, PSB, Italy) were grown as sole crops and in intercropping. In 2023-24, a replacement design (50:50 seeding ratio) was adopted, whereas in 2024-25 the intercropping configuration was modified to favor chickpea productivity through an additive design, maintaining the full chickpea seeding rate while halving carinata density. Crop biomass and seed yield were measured, and system performance was assessed through the Land Equivalent Ratio (LER), Aggressivity Index (AI), Monetary Advantage Index (MAI), and Water Productivity Ratio (WPR). Crop performance was influenced by both weather conditions and intercropping design. In 2023-24, sole carinata produced 3.33 Mg ha⁻¹ of seed and intercropped carinata 2.35 Mg ha⁻¹, whereas chickpea yielded 0.40 and 0.18 Mg ha⁻¹ under sole cropping and intercropping, respectively. In 2023-24, the intercropping system achieved a LER of 1.15 and a positive MAI (+235 € ha⁻¹), indicating agronomic and economic advantages over monocropping. In contrast, the warmer and drier conditions recorded in 2024-25, combined with the modified intercrop configuration, markedly reduced carinata productivity, with seed yield declining to 0.50 Mg ha⁻¹ in sole cropping and 0.01 Mg ha⁻¹ in intercropping, respectively. Consequently, LER decreased to 0.84 and MAI became negative (-530 € ha⁻¹), despite chickpea achieving a high seed yield of 3.17 Mg ha⁻¹ in intercropping system. Carinata-chickpea intercropping showed potential to improve land-use efficiency and profitability under favorable weather conditions. However, system performance was highly dependent on weather conditions and crop arrangement. Optimizing species density and spatial configuration will be essential to improve system stability and facilitate the integration of carinata into EU food-based cropping systems.

Irrigation Consortia in Piedmont: innovation is needed to support modern farming

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Presentation: Poster

In addition to promoting and coordinating the irrigation of large agricultural lands, Irrigation Consortia in Italy carry out important reclamation (especially for excess water) and land improvement, land protection, electricity generation, and maintenance of small and large infrastructures (such as dams, reservoirs, and canals). When equipped with the necessary personnel, operational resources, and planning capabilities, they can offer services not only to farmers but also to local authorities for land protection. The National Association of Land Reclamation, Irrigation, and Land Improvement (ANBI) groups together 141 Italian consortia, but certainly other are in operation in Italy. The Piedmont Region stands out from the national context for its less advanced irrigation consortium structure, which is fragmented, still tied to outdated rules, and almost entirely private. This study aims to describe the current situation of Irrigation Consortia in Piedmont and hypothesize their evolution to make agriculture more resilient to climate change. It is the result of a specific European project (European project MountResilience– HORIZON-MISS-2022-CLIMA-01, 2024–2027). In Piedmont, there are 740 elementary consortia, known as first-degree consortia, with considerable heterogeneity in size, ranging from 1 ha to 91,000 ha of irrigated area. Many of these irrigation entities have a history of managing water for agricultural use dating back over 100 years, linked to the construction of the main canals. For example, the Brobbio-Pesio Irrigation Consortium was founded in 1293, with the construction of the canal of the same name, while the Canale de Ferrari Irrigation Consortium for Land Improvement dates back to 1853. Similarly, the Cavour Canal (85 km) was built between 1863 and 1866. The regulations created then still influence the current irrigation availability of the consortium companies. Since 1999, the elementary consortia have been grouped into 36 Irrigation District Management Consortia (Second-Level Consortia). The criterion used was based on the identification of homogeneous territorial units in terms of hydrographic and functional characteristics and therefore access to irrigation supply sources. However the previous elementary consortia still exist and hold the public concessions for deriving water from rivers and aquifers: geographical aggregation into larger irrigation districts has rarely led to management consolidation and the exploitation of economies of scale. The managers of elementary consortia frequently lack

technical training and do not support the implementation of necessary agronomic and territorial innovations. Digitalization is applied only to control water withdrawal from river. To bring Piedmont closer to the irrigation organization of other regions in the Po Valley, it is proposed to reduce the number of aggregations to 13, through the creation of large land reclamation consortia (public entities) or land improvement consortia (private entities with public management capacity). It is envisaged to encourage a free aggregation of the current 36 irrigation district managers, but a final number is imposed. The key action is the revise the agronomic and territorial functions that will be specific to the new consortia and that are described in this study.

Combining cover crops with herbicides to manage maize weeds in a minimum tillage system

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Abstract ID: 234

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Presentation: Poster

Cover crops (CC) can be grown in the intercropping period or alongside the cash crop to suppress weeds. A two-year field study in a minimum tillage system was conducted in north-west Italy in 2025 and 2026. The objective of the study was to compare two conventional weed management strategies in maize with three different combinations of CC with herbicides. Five treatments were arranged in a randomized complete block design with three blocks: i) pre-emergence herbicide (isoxaflutole + thien carbazon-methyl) applied after maize seeding; ii) post-emergence herbicide (nicosulfuron + rimsulfuron + dicamba) at maize BBCH 14 stage; iii) tillage radish (*Raphanus sativus* var. *longipinnatus*) seeded in autumn in 75-cm wide rows at a 7 kg ha⁻¹ rate and terminated before maize seeding + post-emergence herbicide at maize BBCH 14; iv) crimson clover (*Trifolium incarnatum*) seeded in autumn (30 kg ha⁻¹) + in-row application of pre-emergence herbicide right after maize seeding; v) crimson clover (*T. incarnatum*) seeded the same day as maize (30 kg ha⁻¹) + in-row application of pre-emergence herbicide right after maize seeding. Both CC and weed density and biomass were assessed, as well as maize height, SPAD index and grain yield. Tillage radish developed on average 16.6 g m⁻² prior to termination with glyphosate. In June, crimson clover biomass was significantly higher when seeded in autumn (223.4 g m⁻²) compared to spring seeding (79.4 g m⁻²). However, weed biomass was similar among these two treatments (on average 144.4 g m⁻²), which were found to be less effective than the treatments involving pre- or post-emergence herbicides, in which weed biomass was < 40 g m⁻². Conversely, weed composition was more diverse in plots hosting a CC, especially in the early stages of the crop, with problematic species such as *Sorghum halepense* or *Chenopodium album* being less dominant compared to plots without a CC. Competition from both weeds and cover crops affected the final height of maize, with Crimson clover having the greatest impact when seeded in autumn (157.9 cm); the highest value (233.8 cm) was recorded in

treatment i), followed by treatment iii) (221.1 cm) and treatment ii) (195.7 cm). Also SPAD index was the highest in treatment i) (56.7), while it was significantly lower where maize was growing with crimson clover (on average 50.1); treatments with post-emergence application had intermediate values. The competition between the crop and both cover crops and weeds was also observed in terms of final yields, which were below 8 Mg ha⁻¹ in treatments iv) and v) and over 16.5 Mg ha⁻¹ in the remaining treatments. Using crimson clover reduced the area sprayed with a pre-emergence herbicide, which is generally more persistent in soil. However, it did not provide adequate weed reduction. Using tillage radish alongside a post-emergence herbicide application did not affect the crop growth. However, compared to treatment ii) it provided soil cover during the intercropping period.

Chickpea root and nodulation response to cultivar choice, sowing date and intercropping in a multi-year field study

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Abstract ID: 235

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Presentation: Poster

The study of root development and nodulation in grain legumes remains a relatively underexplored area of agricultural research, particularly under field conditions and in intercropping systems. In chickpea (*Cicer arietinum* L.), most available studies on nodulation have been conducted under controlled conditions and often rely on *Rhizobium* inoculation, whereas chickpea is commonly cultivated without inoculation under Mediterranean farming conditions. This study investigated the effects of cultivar choice and intercropping with common wheat (*Triticum aestivum* L.) on chickpea root traits and nodulation under low-input field conditions. Five chickpea cultivars belonging to the Desi and Kabuli types and originating from Mediterranean countries were evaluated: Nero della Murgia and Sultano (Italy), Castor and Lambada (France), and Castellano (Spain). Each cultivar was grown as sole crop and in intercropping with wheat in a randomized block design with three replicates. Field experiments were conducted in Pisa, Italy, between 2023 and 2025 across four sowing dates (22 February 2023, 31 January 2024, 12 November 2024, and 4 April 2025). One representative chickpea plant per plot was sampled at maturity for a total of 120 observations. Roots were collected using a soil monolith (10 × 10 × 20 cm), washed, separated from nodules, and oven-dried together with aboveground biomass. Nodule biomass was positively correlated with root biomass ($r = 0.43$) and aboveground biomass ($r = 0.52$), and was significantly affected by cropping system ($p = 0.003$), cultivar ($p = 0.020$), sowing date ($p < 0.001$), and the cultivar × sowing date interaction ($p = 0.002$). Nodule biomass was lower under intercropping than sole cropping, higher in Castellano than in Sultano and Lambada, and higher in the January and February sowings than in the November and April sowings. Nodule number was positively correlated with root biomass ($r = 0.46$), nodule biomass ($r = 0.27$), and aboveground biomass ($r = 0.26$), and was influenced only by sowing date ($p = 0.001$). Root biomass was positively correlated with grain yield ($r = 0.48$) and aboveground biomass ($r = 0.39$) and was significantly affected by cultivar ($p = 0.002$) and sowing date ($p < 0.001$). Castellano and Sultano showed higher root biomass than Castor, while the January sowing produced higher values than the February and April sowings. Overall, cultivar and sowing date were the main drivers of chickpea root development and nodulation, whereas the effect of intercropping was comparatively limited, being mainly associated with a reduction in nodule biomass. These findings provide new field-based evidence on chickpea root traits and nodulation under Mediterranean low-input conditions and highlight the importance of cultivar choice and sowing date for belowground development together with the effects of intercropping.

Integrating Conservation Agriculture and Irrigation Systems for Sustainable Quinoa Production in a Mediterranean Environment

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Abstract ID: 236

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Presentation: Poster

Climate change and increasing water scarcity are major challenges for the sustainability of Mediterranean agriculture, requiring the adoption of innovative management strategies capable of enhancing resource-use efficiency and crop resilience. Within this framework, the WaterMellon project aims to develop sustainable and regenerative agricultural systems adapted to arid and semi-arid environments through the integration of conservation agriculture practices, efficient irrigation techniques, and digital monitoring tools. A field experiment was established at the CREA-CI in Foggia (Southern Italy) in 2025/26 season to evaluate the performance of two crops: durum wheat (*Triticum durum* Desf.) and quinoa (*Chenopodium quinoa* Willd.) grown in a 2-year rotation. The quinoa crop was included as alternative crop to promote diversification and improve the resilience of cereal cropping systems. The experimental design compared two soil management strategies, Minimum-Tillage and No-Tillage (in a long-term experiment on conservation agriculture), with two irrigation methods: surface drip irrigation (SUR) and subsurface drip irrigation (SUB). Crop performance was assessed through agronomic measurements and continuous soil monitoring. Soil moisture probes were installed in the quinoa plots to continuously measure soil volumetric water content and soil temperature at depths of 5, 15, and 25 cm. The sensors provided detailed information on soil moisture and temperature dynamics under the tillage and irrigation treatments, allowing the evaluation of soil water availability throughout the growing season. Sensor data were integrated with phenological observations, crop growth analysis and seed yield and quality, to evaluate the effectiveness of tillage practices and irrigation systems. Continuous monitoring demonstrated that in No-Tillage system the SUB system sustained higher soil moisture than SUR in the 15 and 25 cm depths, mainly in the second half of growing season. This deep-layer water buffering mitigated summer heat stress, delaying canopy senescence and extending quinoa's growing cycle by 5-7 days. Ultimately, the combination of No-Tillage and SUB, optimizes root-zone hydro-thermal dynamics, offering a robust climate-adaptation strategy for Mediterranean agroecosystems. These findings contribute to the identification of sustainable agricultural solutions, demonstrating how integrating crop diversification, conservation agriculture practices, and continuous soil monitoring can develop more resilient and resource-efficient cropping systems capable of coping with current and future climate challenges.

Evaluation of summer intermediate oilseed crops for double-cropping systems in northeastern Italy

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Abstract ID: 245

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Presentation: Poster

The introduction of summer intermediate crops could increase resource-use efficiency in EU cropping systems. However, crop establishment and productivity during summer are constrained by heat and water stress, making species selection and management practices key factors for the viability of double cropping systems. This study investigated the suitability of sunflower, soybean, and camelina as summer intermediate crops under the pedoclimatic conditions of northeastern Italy. A field experiment was carried out at the University of Bologna Experimental Farm (Cadriano, Bologna, Italy) during summer 2025. The trial was arranged as a randomized complete block design with four replicates. An ultra-early sunflower hybrid (N4H161 CL, Nuseed), two soybean varieties (Compositor and Comandor, group 000, Lidea), and a camelina drought-tolerant line (V192, CCE) were tested. Crops were sown on June 10 using a precision plot seeder (Vignoli Group) and irrigated to ensure uniform establishment. No fertilization was applied. Emergence, plant height, cycle length, seed yield, seed quality, and water use efficiency were assessed. Water use efficiency was calculated as seed yield divided by cumulative estimated crop evapotranspiration, obtained as $\Sigma(ET_0 \times K_c)$. In addition, soil bulk density was determined at a depth of 0-0.2 m, while soil nitrate concentration was measured at 0-0.6 m at sowing (T0) and before harvest (T1), and compared with the fallow control plot. Weather conditions during summer 2025 were generally close to the long-term average, although June was hotter (+3°C), and drier (-20 mm). Sunflower showed excellent establishment (7 plants m⁻²), completed its cycle in 118 days, and achieved 2.0 Mg ha⁻¹ seed yield. Soybean emergence averaged 38 and 35 plants m⁻² for Compositor and Comandor, respectively. Both soybean varieties completed their cycle in 122 days, yielding 0.97 Mg ha⁻¹ and 0.80 Mg ha⁻¹ of seed, respectively. In contrast, camelina establishment was severely impaired (<10% emergence), by high June temperatures and soil crusting following irrigation, resulting in extreme weed competition and negligible seed yield. Water use efficiency was the highest in sunflower (5.41 kg ha⁻¹ mm⁻¹), followed by soybean Compositor (2.77 kg ha⁻¹ mm⁻¹) and Comandor (2.28 kg ha⁻¹ mm⁻¹). Bulk soil density increased significantly from T0 to T1 ($P < 0.05$; +0.65 g cm⁻³), indicating progressive soil compaction; however, no significant differences were observed among species and the fallow control at harvest. Soil nitrate concentration at harvest was not significantly affected by crop species, soil layer, or their interaction, although a marginal crop effect was detected ($P = 0.067$). LSD mean separation suggested a tendency toward higher residual nitrate under soybean Comandor compared with sunflower. Sunflower and soybean were the most promising summer intermediate oilseed crops, with sunflower showing the best yield performance and apparent water use efficiency. Camelina was

mainly constrained by establishment failure, suggesting that its potential depends strongly on sowing conditions and soil surface management. Further research is needed to optimize crop establishment and water management, and to evaluate these species after different preceding crops, including winter cereals and grain legumes, to support their integration into diversified EU cropping systems.

Self-reseeding *Medicago intertexta* for resilient Mediterranean forage systems: effects of management systems and intercropping on forage performance

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Abstract ID: 249

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Presentation: Poster

Mediterranean forage systems are increasingly threatened by climate change, particularly by rising temperatures, irregular rainfall patterns, and more frequent drought events, which negatively affect forage productivity, persistence, and feed availability. At the same time, agricultural intensification has traditionally relied on high levels of external inputs, often at the expense of environmental sustainability. Consequently, the development of resilient, low-input forage systems has become a priority for Mediterranean agriculture. Diversified agroecosystems, including species-rich forage systems, intercropping, and crop rotations, are recognized as effective strategies to enhance resource-use efficiency, productivity stability, and resilience under variable climatic conditions. The rich forage biodiversity of the Mediterranean Basin, shaped by long-term agro-pastoral practices and diverse pedoclimatic conditions, represents a valuable source of species adapted to stressful environments. Among these, self-reseeding annual legumes have attracted growing interest due to their ability to persist through soil seed banks regulated by hard-seed dormancy, ensuring natural regeneration and greater pasture stability. In particular, species of the genera *Medicago* and *Trifolium* provide multiple ecosystem services, including biological nitrogen fixation, improved soil fertility, high-quality forage production, and adaptation to drought-prone environments, making them valuable components of sustainable Mediterranean forage systems. Among Mediterranean annual legumes, *Medicago intertexta* (L.) Mill. is a promising species due to its forage and seed production potential, tolerance to salinity, and high palatability; however, information regarding its agronomic management remains limited. This study evaluated forage productivity and quality (crude protein content) of *M. intertexta* under different management and intercropping systems in a Mediterranean environment. The experiment was conducted during two consecutive growing seasons (2023/2024 and 2024/2025) at the “Sparacia” experimental farm of the University of Palermo (Sicily, Italy). *M. intertexta*, *Lolium multiflorum* Lam. (annual ryegrass) and *Trifolium alexandrinum* L. (berseem clover) were grown as pure stands and in binary substitutive intercrops arranged in alternate rows at a 50:50 seeding ratio. Treatments were arranged in a split-split-plot design with four replications. Five utilization strategies were compared: four grazing-simulation treatments obtained by combining cutting intervals of 28 or 35 days with stubble heights of 3 or 8 cm, and a single-cut haymaking treatment. Across the two years, forage productivity and quality were significantly influenced by species composition and management system. *M. intertexta* was better adapted to low-intensity management, whereas berseem clover showed superior performance under high-intensity utilization, likely due to its strong regrowth capacity. Intercropping provided

advantages in terms of resource-use efficiency and productivity, although responses varied according to species combination and management intensity. While mixtures often enhanced biomass production, a trade-off with forage quality was occasionally observed, indicating that species interactions may differently affect yield and nutritive value depending on management conditions. These findings highlight the importance of selecting appropriate forage mixtures to optimize both agronomic performance and forage value under Mediterranean conditions.

Temporary grassland and fertilization shape weed communities over 30 years, revealed by DNA metabarcoding and the germinable seedbank

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Abstract ID: 251

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Presentation: Poster

In Ecological Weed Management (EWM), agricultural practices act as ecological filters: lower-disturbance, lower-resource configurations are predicted to favor more diverse, less competitive weed communities, while high-disturbance, high-resource systems select fast, ruderal ones. Because EWM aims for long-term outcomes, soil weed seedbank characterization is necessary to evaluate whether a change in management durably reshapes the weed community. In this study, we explored a 30-year field experiment in the Piedmont region, crossing crop rotation as a disturbance gradient (continuous maize, high disturbance vs. temporary grassland, low disturbance) with fertilization as a resource gradient (no fertilization, farmyard manure, slurry, and urea). We characterized the resulting weed seedbank using two complementary approaches: the conventional germinable seedbank (GSB) and DNA metabarcoding (MTB) in its first application to a weed seedbank, and we tested whether either or both agricultural practices reshaped seedbank size and diversity. Weed communities were structured along both disturbance and resource gradients, with low disturbance and low resources supporting more diverse and even communities. Moreover, seedbank size was reduced by 54% in low disturbance setting ($\approx 3,000$ vs ≈ 6500 seeds/m²). Both characterization methods converged on this signal, albeit with complementary inputs: GSB detected the fertilization effect more clearly, while MTB, recovering a far broader community (470 species across 178 genera against 29 with GSB), captured the effect of temporary grassland rotation. These results show that diversifying the rotation with temporary grassland is an effective long-term redesign for steering the weed seedbank toward smaller, more diverse, and potentially more manageable communities. They also illustrate both the promise and the limits of molecular tools in this transition: DNA metabarcoding offers a richer, faster, non-destructive inventory of seedbank biodiversity, but pairing it with the germinable method remains necessary to retain agronomic relevance.

Hay production in an organic almond-based agroforestry system in south-eastern Sicily

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Presentation: Poster

Almond orchards, a characteristic feature of Sicilian landscapes, provide suitable conditions for agroforestry development. This study evaluated land-equivalent ratio, land savings, weed suppression, and forage crop performance in relation to tree proximity and canopy orientation in a Mediterranean almond-based agroforestry system, with the aim of assessing its potential for sustainable intensification. The ongoing field trial was established in a 35-year-old organic almond orchard (*Prunus amygdalus* Batsch cv. Pizzuta d'Avola) in Noto, Sicily (36°50'N, 15°02'E; 19 m a.s.l.), on a loamy soil during the 2025-2026 growing season. Barley (*Hordeum vulgare* L. var. Tonic), burr medic (*Medicago polymorpha* L. var. Scimitar), and their intercrop were grown within the almond alleys (5×5 m spacing) and in adjacent sole-crop plots and sole-almond trees, arranged in a randomized block design with three replicates. Forages were manually sown in December 2025. At the boot-heading stage of barley and flowering stage of burr medic (April 2026), forage dry biomass was measured using 0.5 m² quadrats. Crop and weed biomass were sampled at three positions within the alley: 1 m west (1W) and east (1E) of the tree row, and at the alley center (2.5 m from the tree rows), representing different levels of tree proximity and canopy influence. The land equivalent ratio (LER) was calculated as the sum of the ratios between intercrop and sole crop yields of each species. The land saving (%) was calculated as $[1 - (1/\text{LER}) \times 100]$. Data were analyzed by a mixed-effect model and means separated by Tukey's HSD at $P \leq 0.05$. The crop yield in agroforestry was not affected by tree proximity and canopy orientation ($P = 0.051$), although a trend was observed with the center and 1E higher than 1W. The species effect was significant ($P \leq 0.05$), with burr medic and barley-burr medic intercrop higher than barley. Position, species and the interaction were significantly different ($P \leq 0.05$) on weed dry biomass, with the control (sole-almond) group showing the highest values, while the burr medic 1W, and barley-burr medic intercrop 1W and 1E, the lowest (on average -66%). Although the average crop yield was $\approx 40\%$ lower in agroforestry than in sole-crops, burr medic or the intercrops allowed to improve the LER versus sole-crops. The partial LER was lower than 1 in barley and burr medic 1W, while higher than 1 in burr medic 1E and at the center, and in the barley-burr-medic intercrops at all tree proximity and canopy orientation. These findings indicate that crop performance in the almond-based agroforestry system was only marginally influenced by tree proximity and canopy orientation, while species selection played a major role in productivity and weed suppression. Despite lower crop yields compared with sole cropping, burr

medic and especially the barley-burr medic intercrop improved land-use efficiency, with partial LER values exceeding 1 in most agroforestry positions. The total LER, including the almond component, will be determined following almond harvest in August. Acknowledgements. Funded by PRIMA 2024 - Section 2. Topic 2.2.1. Project "SCALARE - SCaling Agroforestry by living LABs for Resilient Mediterranean agro-Ecosystems" (CUP: J43C25000480001).

PRO-MAIS: An Integrated Framework for Aflatoxin Risk Mitigation in Maize (*Zea mays* L.) under Mediterranean Growing Conditions

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Presentation: Poster

Aflatoxin contamination is among the most critical threats affecting maize production worldwide, compromising food and feed safety while causing significant economic losses. Climate change, through increasing drought and heat stress events, has enhanced maize susceptibility to *Aspergillus flavus* infection, leading to higher contamination risks in Mediterranean environments. In Tuscany, particularly in the Valdinievole district, increasing aflatoxin occurrence has highlighted the need for sustainable mitigation strategies. PRO-MAIS aims to evaluate integrated agronomic, biological and digital approaches to reduce aflatoxin contamination and improve maize resilience under Mediterranean conditions. The project is based on the hypothesis that combining preventive agronomic practices, biological control agents and advanced monitoring technologies can reduce fungal development and support farmers' decision-making. Field activities will be carried out in four commercial maize farms representative of the Valdinievole area. Agronomic strategies, including drought-tolerant hybrids, deep tillage with crop residue incorporation and alternative soil management practices, will be evaluated for their potential to reduce pathogen inoculum and improve soil functionality. Soil properties and crop responses will be monitored to assess their relationship with aflatoxin risk. A second component focuses on biological control agents (BCAs) based on antagonistic fungal strains. Their effectiveness in suppressing aflatoxin-producing populations of *A. flavus* will be assessed under local conditions. In addition, microbiological and metagenomic analyses will characterize soil, air and grain microbial communities, improving the understanding of ecological interactions involved in toxin production. The use of atoxigenic *A. flavus* strains is considered one of the most promising biological strategies for aflatoxin mitigation. Precision agriculture tools will also be investigated through the integration of weather stations, soil moisture sensors, microbiological air samplers and drone-based multispectral and thermal imaging. These technologies will support the development of practical monitoring protocols for early risk

assessment. Expected outcomes include the identification of effective agronomic and biological mitigation strategies and the development of integrated monitoring systems to support sustainable maize production under increasing climate-driven mycotoxin risk.

The Agroecology Partnership as a research programme for enabling EU-wide food system transformation

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Presentation: Poster

The present global scenario, characterized by polycrisis (international conflicts, climate change, environmental degradation and biodiversity loss, socio-economic inequality among others), has underlined the fragility of the current agricultural context in the EU. With growing debate in both the scientific community and the general public, the importance of moving towards food systems capable of ensuring food sovereignty and healthy diets for all has been identified as a political priority. This has raised the need for a systemic transition, as highlighted by several policy initiatives such as the UN Sustainable Development Goals and the European Green Deal. Agroecology (AE) is now recognized globally as one of the most promising ways to address the strategic challenges facing agrifood systems. AE is considered as the ecology of food systems, comprising sciences, a set of practices, and socio-political movements which aims at developing sustainable agrifood systems. However, several hurdles to its application have been identified. At the research level, a lack of experimental long-term data series on agroecosystems' functioning under AE management entails a lack of sound indicators and methodologies to quantify context-relevant system performances. At the policy level, the fragmentation of strategic initiatives restricts a coherent policy framework to support this transition. At the end user level, the perceived lower profitability and higher knowledge intensity of AE compared to conventional farming approaches hinder its adoption by farmers; while insufficient awareness of the costs and added value of AE practices and insufficient price incentives pose threats on the consumers' preference for products from farms that adopt them. The AGROECOLOGY Partnership, funded by Horizon Europe from 2024 to 2033, unites the European Commission and 111 partners across 31 countries and aims to address these barriers. To do so, it will 1) enable a better scientific comprehension of agroecological processes from farm to landscape levels, 2) boost place-based policy innovation and 3) improve the flow and uptake of knowledge and awareness about AE. The Partnership consists of eleven work packages: the University of Gastronomic Sciences is involved in three of them and co-leads the one focused on Education. Operationally, the Partnership combines the establishment of a European network of Living Labs (LLs) and Research Infrastructures (RIs) with the funding of transnational R&I calls. LLs act as place-based, multi-actor settings where farmers, advisors, researchers, policy makers and citizens co-design and test agroecological practices under real-life conditions. They define research priorities and knowledge needs, thereby providing input to calls and supporting the uptake of project results. RIs provide services for measurement and experimentation, including data and data management, as well as scientific platforms for assessing AE performance. In this regard, an innovative and comprehensive monitoring framework is being developed to assess the holistic performances of the AE transition in Europe. The Partnership will contribute to filling existing knowledge gaps on AE,

promoting user-driven research on AE, addressing the wide geographical/territorial specificities in the EU through place-based approaches with long-term perspectives, and improving the sharing of knowledge within and across EU countries and beyond.

Preliminary assessment of agroforestry systems for metal-contaminated soils phytomanagement

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Presentation: Poster

Phytomanagement of contaminated soils provides nature-based remediation while enabling industrial crop cultivation without competing with food production. Although numerous species show potential for metal phytoextraction and phytostabilization, field-scale validation remains scarce. Since contaminated soils are typically degraded, testing innovative agronomic practices like intercropping or agroforestry is highly relevant. Four agroforestry systems were evaluated at a former illegal landfill contaminated primarily with Pb (1263 mg kg⁻¹ ss), located in Castelvetro di Modena (44°31'55"N; 10°54'08"E). All systems utilized *Populus nigra* L., specifically the *P. nigra* × *P. maximowiczii* hybrid, selected for combining metal phytomanagement and biomass production. Poplar was grown in monoculture and intercropped with three herbaceous species: *Brassica juncea*, a metal hyperaccumulator oilseed brassica, *Lablab purpureus*, a Pb-tolerant, soil-improving legume, and *Chrysopogon zizanioides* L. (vetiver), a resilient, Pb-tolerant perennial bioenergy grass. A randomized block design was established in February 2025. Poplar saplings (1 m) were transplanted at an extremely high density (11,377 plants ha⁻¹) as done in other phytomanagement systems. Management was entirely manual, and herbaceous crops were harvested at peak biomass to maximize metal uptake, quantified via ICP-OES. The statistical analysis accounted for two covariates: a heavy *Medicago sativa* infestation in previously uncultivated soil, and plot-specific soil Pb concentrations. After the first year, no significant differences were observed in the estimated poplar biomass calculated using allometric equations across the different systems (averaging 0.27 kg per plant); rather, there was a negative effect of increasing Pb concentrations in the soil on the SPAD values measured one month before harvest (5.9-36.4). Among the herbaceous crops, vetiver achieved the highest biomass production (1.35 Mg ha⁻¹), while brassica had the lowest, and lablab had intermediate values significantly influenced by the soil Pb concentration as a covariate. For all crops, as soil metal concentrations increased, concentrations in the aboveground biomass also increased. Vetiver surprisingly showed a nearly 7-times higher shoot Pb uptake than Brassica, while Lablab exhibited decreasing values as the soil Pb concentration increased. Considering the agronomic systems, the highest phytoextraction yields were obtained with poplar intercropped with vetiver (21 g ha⁻¹), and the lowest from the intercropping of poplar with Brassica (-76%). *Medicago* infestation acted as a significant covariate on this parameter, leveling the differences between the systems when included in the analysis. These preliminary results indicate that agroforestry systems can be a more valuable option than poplar monocultures for soil phytomanagement, where perennial, resilient crops may outperform traditional "hyperaccumulators", as the latter often show

limited resistance to the biotic and abiotic stresses of real-world contaminated soils. Data from 2026 and 2027 will be further analyzed to confirm these initial findings. This study was funded by the project EDAPHOS. HORIZON-MISS-2022-SOIL-01 (Research and Innovation actions to support the implementation of the Soil health and Food Mission). Topic: HORIZON-MISS-2022-SOIL-01-04. The EDAPHOS project has received funding from the European Union's Horizon Europe research and innovation program under grant agreement No. 101112768.

Ontologies for agricultural robotics: mapping the mismatch between formal categories and farmers' performance judgements

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Presentation: Poster

Digitalisation produces data, not knowledge. As agricultural robotics moves from data collection towards the automation of decision and action, the categories embedded in machines increasingly govern what a system can perceive, judge, and do in the field. Ontologies, defined here as formal, machine-readable vocabularies that define concepts and their relations, are also artefacts through which this categorisation is encoded among actors and for automation. Ontologies were built primarily for data interoperability and to organise terms into logically defined, computationally tractable relations. This study asks a prior question, poorly examined in the agronomic literature: by which epistemic pathway, and from whom, did ontologies enter agriculture, and what is lost when situated agronomic knowledge is rendered in this form? Drawing on a review of technical and scientific literature, we propose a conceptual framework to enhance the design of new ontologies. We posit the dual nature of an ontology. On the one hand, an ontology is a formal, machine-readable artefact; on the other hand, it is a symbolic artefact through which actors formalise and circulate knowledge. Agriculture strains formal ontologies on machine-readable artefacts because it manages living beings outdoors, where the meaning of a category shifts with the biophysical and sociotechnical situation, potentially altering the interpretation of relations and priorities. While for a machine a concept has to be pinned to stable relations, farmers' categories are more ephemeral: the same plant is a crop, a volunteer, a cover, or a weed depending on the time of judgment. A robot's ontology hardly holds this flexibility, thus silently resolving the mismatch in favour of the formal version. Two illustrative cases show what this costs. First, a weeding robot can classify a companion crop as a weed and remove it, whereas the farmer's tacit ontology would have tolerated it in that context. Second, the definition of work capacity can hardly be aligned between the formal ontology of a robot manufacturer versus the situated capacity the farmer expects under this field's real conditions. We therefore call for the mismatch between technocentric ontologies and farmers' tacit ontologies to be made explicit rather than implicitly absorbed and overlooked. Practically, this means treating performance as multi-dimensional in design; naming whose categories a recommendation encodes; and reserving formal ontologies for interoperability while keeping situated judgement with the farmer. The contribution provides a shared framework for designers and farmers to negotiate, before robots are trusted to act in their place.

An Operational hybrid MRV Digital Twin of soil C removals: Assessing Cost-Accuracy-Precision Trade-offs and Agronomic Co-benefits for Cropping Systems Redesign

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Presentation: Poster

Regulatory mandates and market demands push agrifood companies to incentivize regenerative agriculture (RegAg) adoption, highlighting the urgency for high-integrity verification frameworks. However, implementation is hindered by a data-curation cost paradox: Tier 3 ecosystem models require expensive logs, while Tier 1 ones triggers severe uncertainty-discounts. This study deployed a hybrid operational MRV framework for soil C removals (Remote-C). The objective is to execute a Cost-Accuracy-Precision (CAP) simulation exercise in commercial farms to identify the financial and technical tipping point of input data curation, verifying CRCF-auditable soil C removals certificates and agronomic co-benefits to support cropping systems redesign. Remote-C integrates remote sensing products with spatialized soil C modelling and has been tested in 5 Commercial Farms in Piacenza province with a 3-year wheat-maize-tomato rotation implementing winter cover crops and full residue incorporation, under minimum tillage. Daily, pixel-scale RUE-based Production Efficiency Model (PEM) simulations assimilated S-2 phenometrics and GLAI time series to simulate AGB and organ-specific C inputs. Tillage dates and residues incorporation timelines were explicitly derived via multi-temporal optical and S-1 SAR imageries. Management and crop data feed a spatialized RothC model initialized via proximal soil sensing maps calibrated with smart soil sampling. Multi-ensemble Monte Carlo loops evaluated CAP trade-offs by contrasting High-Data site-specific (sensing mode), Medium-Data, and Low-Data soil/crop generic input data streams. Full climate cooling

benefits were simulated by coupling biogeochemical with biophysical radiative forcing into the FaiR climate response model. Long-term permanence was modelled ex-ante and evaluated ex-post via soil re-sampling 2 y after a 3-y RegAg adoption vs a 5-y RegAg continuous scenario. RS products achieved robust performance, reaching practice detection accuracies >85%. The PEM engine simulated AGB with high accuracy across main and cover crops. Crucially, growth curves revealed that, post-cover crop termination, main crops exhibited faster, significantly better recovery to late-spring thermal stresses and during pre-flowering stages. Remote-C operated in "sensing mode" satisfactorily reproduced short-term SOC dynamics, reducing prediction bias compared to generic inputs. Absolute mean model bias remained strictly below the Pooled Measurement Uncertainty. Pixel-based modelling captured fine-scale estimated removals population, satisfying the CRCF 90-90 rule while reducing the uncertainty deduction factor to 16%. Agronomically, combined RegAg practices achieved a measured mean annual soil C sequestration rate of 1.5 Mg C/ha over the 3-year period, generating >14 certified units and a diesel savings of >100 L/ha. Re-sampling 2-y after practice abandonment showed that SOC dropped sharply back to initial levels. This validates that short-term adoptions provide only a transient cooling effect, with cumulative cooling benefits reversed within <20 years due to back-to-baseline scenario. Conversely, sustained practices ensure continuous SOC accumulation securing a climate cooling effect beyond 50 years. The CAP matrix confirms that while meteo and crop calendars can be safely generalized (Low-Data), field-specific initialization of initial SOC (High-Data) and practice verification are mandatory to issue high-integrity, bankable soil C certificates while certifying low-carbon raw materials sourced from RegAg. This framework provides the data-driven foundation to realistically de-risk and redesign regenerative, low-emission cropping systems at scale.

Fostering agroecology through a Living Lab network approach: The SUNRISE project

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Presentation: Poster

Agroecology is recognized as a transformative approach that leverages both modern scientific methods and local knowledge to reconfigure farming systems. SUNRISE is a comprehensive, pan-European initiative funded by the Agroecology Partnership (grant agreement No. 101132349), designed to accelerate the agroecological transition by establishing a network of Agroecological Living Labs (AELs) across 10 countries. By integrating research infrastructures, local farming communities, industry stakeholders and policy makers, SUNRISE fosters an environment of co-creation, experimentation, and knowledge exchange to drive the agroecological transition. In each AELL, a multi-actor team (MAT) identified local agronomic challenges, set transition goals, and co-designed innovative solutions addressing six key sub-themes across diverse cropping/farming systems: (i) soil health (ii) crop diversification (iii) reduced inputs (iv) crop/animal production (v) biocontrol (vi) biodiversity and ecosystem services. The Italian AELs, officially funded on March 2025 under the name of ALL-Tuscany, is addressing all of the above-mentioned sub-themes. Methodology. SUNRISE employs an 11-step participatory approach that systematically guides the co-creation process. The first step consists of (i) the establishment of MATs. MATs are responsible for the completion of all following steps, starting with (ii) the collaborative identification of local priorities, and (iii) the identification of sites for on-station and on-farm trials, followed by the (iv) co-design of improved agroecological practices, (v) the test of the potential innovations and (vi) results evaluation. Finally MATs are responsible for the (vii) planning and (viii) implementation of knowledge sharing activities, and for (ix) the definition of successful innovations, to be used to provide (x) guidelines on AELs establishment and functioning as well as (xi) policy recommendations. SUNRISE AELs take stock of synergies between research infrastructures and local lighthouses (experimental farms) to validate and fine-tune agroecological innovations. By applying both "hard" methodologies and "soft" methodologies, SUNRISE ensures that the resulting practices will not only be technically sound but also practically relevant and readily adoptable. On the "hard" side, scientific trials are conducted both on-station and on-farm, using standardized

protocols for data collection and evaluation. On the “soft” side, participatory workshops and focus group discussions capture the tacit knowledge of practitioners, ensuring that technical innovations are aligned with real-world conditions. Current/expected outcomes. SUNRISE aims to enhance agricultural productivity and environmental sustainability, serving as a model for participatory innovation in agroecology, and providing valuable insights to inform national policies and EU strategies. A key outcome of the project is the definition and refinement of a set of successful agroecological practices tailored to different EU contexts. Additionally, SUNRISE aims to establish a permanent network of AELs that will continue beyond project’s duration, contributing to shaping the future of EU agriculture. The Italian participatory trials have been set up at four lighthouse farms: (i) a vineyard where different self-reseeding legume cover crops are tested in the under-vine area, (ii) an olive farm where prunings are composted with earthworms instead of burning, (iii) an arable farm where intercropping combinations are tested separately for durum wheat (*Triticum turgidum* subsp. durum) and lentil (*Lens culinaris*), each with other species, and (iv) a livestock farm where virtual fencing is tested on pasture bullocks.

Digital Ecosystems as Levers for Bio-Districts Agroecological Redesign: Innovation Technological Autonomy, and New Producer-Consumer Relationships

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Presentation: Poster

Achieving sustainable agricultural transitions requires not only agronomic innovation but a systemic reconceptualisation of the organisational and relational structures of agri-food territories. This paper addresses the following overarching research question: to what extent can integrated digital ecosystems simultaneously lower structural barriers to the adoption of innovation and reshape producer-consumer relationships toward co-created agroecological value within Bio-Districts? These two dimensions are treated as complementary facets of a single governance challenge rather than isolated phenomena, highlighting the need for socio-technical infrastructures capable of supporting not only collective learning processes but also territorial coordination. Bio-Districts constitute privileged settings for this inquiry, aggregating heterogeneous actors, organic producers, conscious consumers, local authorities, researchers, and certification bodies, united by a shared territorial vision. Yet their capacity to translate that vision into widely diffused innovative practices remains constrained by structural barriers of a technical, socio-economic, cultural, and institutional nature. Information fragmentation hampers supply-chain coordination, elevated transaction costs reduce the competitiveness of small-scale farms, and the absence of shared monitoring frameworks limits evidence-based policy development. A further underestimated barrier concerns digital dependency: proprietary platforms may expose Bio-Districts to lock-in dynamics, concentrating data ownership and decision-making power in external hands, thereby undermining territorial governance autonomy. In this context, designing digital infrastructures is not only a technical issue, but a strategic governance concern linked to the long-term resilience and self-determination of the territories. The participatory action research framework applied in this project posits that integrated digital ecosystems may help address both facets of the research question through three synergistic axes. First, shared digital farm notebooks and territorial coordination platforms may contribute to transforming the Bio-District into a hub of shared agronomic knowledge, reducing information

asymmetries and coordination costs, a prerequisite for meaningful innovation diffusion. Second, digital tools connecting producers directly with purchasing groups and civic networks have the potential to shorten supply chains, strengthen relational trust, and enable the co-creation of economic and social value. Third, digital product passports incorporating synthetic agroecological performance indicators have the potential to make the ethical and environmental commitments of farming enterprises legible to consumers and policymakers, fostering market differentiation and participatory governance. The methodology is grounded in participatory co-design principles, whereby digital tools are developed and iteratively refined through structured dialogue among researchers, farmers, and local communities following a territorial living-lab logic. Technological autonomy is not merely a design constraint but an expected outcome: the project aims to equip Bio-Districts with community-governed digital infrastructures under collective territorial control. Preliminary outcomes include enhanced organisational coordination within participating Bio-Districts, increased producer awareness of data governance issues, and an emerging evidence base for territorially embedded decision-making. This contribution demonstrates that the eco-digital transition, when governed by a participatory and place-based approach, can serve as a concrete lever for applied agroecology.

Temporary intercropping with grain legumes succeeds in increasing grain yield and quality of durum wheat

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Presentation: Poster

Intercropping is one of the most effective agroecological practices to diversify Mediterranean arable cropping systems, where winter cereals' share is dominant and rotations with grain legumes could be hindered by pedoclimatic conditions and market opportunities. Several studies proved that permanent intercropping with grain legumes could help overcoming some of the most yield limiting factors for durum wheat (*Triticum turgidum* subsp. *durum* (Desf.) Husn.), namely nitrogen use inefficiency and weed pressure. These latter are maximally severe in organic farming, due to the ban in the use of soluble mineral fertilisers and herbicides. Nevertheless, mechanical harvest and grain separation of wheat and legume permanently intercropped could be expensive or difficult. Temporary intercropping (TIC) strategies where legumes are grown as facilitative components and green manured at early stages to support wheat growth could be promising alternatives. In 2009-2012, replicated field experiments were carried out at the Research Station of Rottaia of the Department of Agriculture, Food and Environment of the University of Pisa (San Piero a Grado, Pisa, Italy) to compare three different TIC treatments (durum wheat intercropped with pigeon bean, *Vicia faba* var. *minor* Beck. cv. *Scurio di Torre Lama*, hairy vetch, *Vicia villosa* Roth. cv. *Capello*, and field pea, *Pisum sativum* L. cv. *Corallo*) with a sole crop of durum wheat (cv. *Claudio*) fertilised at 5 different mineral N fertiliser rates (i.e., unfertilised, 40, 60, 120, 180 kg N ha⁻¹). The experimental layout was a 1-way randomised complete block design with three replications. The companion crops were sown simultaneously on alternate rows following an additive design, with 400 seeds m⁻² for wheat and 80, 100, 200 seeds m⁻² for, respectively, pigeon bean, pea and vetch. Wheat and legumes were displaced on rows 18 cm apart in the TIC treatments, whereas in the control treatments wheat was grown with an inter-row space of 36 cm. The legumes were terminated by inter-row cultivation at early stem elongation stage of wheat. No other crop management operations were performed. Over the three years, pigeon bean resulted the most productive legume at stem elongation phase of wheat. Its fast growth led to significantly depleted biomass of companion wheat in one year over three. TIC treatments including vetch and pea showed instead stably wheat yields statistically similar to the unfertilised control but higher than it in absolute terms in 2010 and 2011. Interestingly, all TIC treatments showed in one year higher kernel protein content of wheat compared to the unfertilised

control, overcoming the standard threshold of 12% w/w required by pasta-making industry. We argue that the nitrogen released into the soil by the mineralisation of the biomass of the legumes might have sustained the grain filling processes of the wheat. Furthermore, the soil cultivation occurred during the green manuring operation could have boosted the mineralization of soil organic N pools, thus resulting in higher N availability at late wheat growing stages. This could be an advantage in face to top-dressing organic fertilisation, that is usually done before stem elongation, thus limiting the benefits for late crop growth.

Assessing the impacts of increasing agroecological diversity of practices on Yields, Income and Costs in the Global South: preliminary results

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Abstract ID: 284

Session: 3. RI-PROGETTAZIONE

Presentation: Poster

This study builds on a meta-analysis evaluating the impacts of agroecological transitions on farm economic performance across the Global South. Synthesizing evidence from more than 350 primary studies, it quantifies shifts from baseline systems to diversified agroecological interventions, defined as systems applying at least two agroecological practices. Three socio-economic indicators are assessed: crop yield, gross income, and production costs. A central methodological contribution is the practice-based characterization of interventions and comparators through the JRC IMAP-Farming Practice framework. Rather than adopting a rigid “conventional” versus “agroecological” binary, the analysis classifies the management practices reported in each pairwise comparison. Descriptive information and technical keywords from primary studies were coded through expert elicitation, accounting for differences in nutrient management, soil conservation, pest control, crop diversification, livestock management, and other agronomic components. This approach treats agroecological transitions as changes in the number, diversity, and interaction of practices, rather than as the adoption of a single technology. Results show a significant “triple win”: agroecological transitions are associated with a 14.3% increase in crop yields, a 44.5% increase in gross income, and a 36.5% reduction in production costs relative to comparator systems. Yield performance is moderated by pedoclimatic conditions, with larger advantages in cooler, more stable climates and soils with lower clay content. Economic benefits are more consistent across spatial scales and irrigation regimes, suggesting stronger dependence on management choices, input substitution, and farm-level economic conditions than on biophysical constraints alone. The practice classification reveals marked asymmetry between systems. Comparators include on average 2.0 coded practices, often centered on mineral fertilization, herbicide restrictions, crop rotation, improved varieties, or other baseline practices. Interventions are more complex, averaging 6.1 coded practices and encompassing broader bundles. Frequent intervention practices include organic farming, nitrogen-fixing crops, crop diversification, intercropping, green manure, biological control, compost application, mechanical weed control, crop rotation, and reductions or bans on synthetic fertilizers.

and pesticides. Thus, the literature generally compares relatively simple or moderately diversified baselines with more integrated agroecological bundles. However, key limitations remain. First, JRC-code classification was performed by a limited number of agronomists, while the detail used to describe cropping systems in primary studies varied substantially, making attribution partly uncertain. A conservative keyword-based coding principle ensured consistent treatment across comparisons; nevertheless, involving a larger expert panel would improve robustness and reduce subjectivity. Second, the study highlights a reproducibility challenge: when primary studies move beyond experimental plots to broader spatial scales, descriptions of intervention and comparator practice systems often become less detailed. Third, attributing each JRC practice code to Gliessman's agroecological transition levels remains partly subjective, despite the iterative process used to compare, discuss, and harmonize classifications. Future research should address these challenges through a participatory process involving experts and farmers, aimed at developing a robust Index of Agroecological Practices Diversity. Structured with up to five digits, the index would count practices attributed to Gliessman Levels 1–5 for both systems, moving beyond binary comparisons and enabling more refined, reproducible measurements of agroecological complexity, while also clarifying which practice combinations drive observed socio-economic outcomes across contexts.

Effect of living and dead mulching on grain yield, weed control and soil moisture in grain legumes

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Abstract ID: 288

Session: 3. RI-PROGETTAZIONE

Presentation: Poster

Increasing the cultivation of grain legumes, a group of leguminous crops native to the Mediterranean, is a key component of the European strategy for developing a sustainable, resilient, and self-sufficient food system. Despite their agronomic and nutritional benefits, grain legumes currently occupy less than 3% of the EU arable land due to low and unstable yields, largely caused by climate change and severe weed pressure. Dead mulching (by organic residues) and living mulching (through cover crops) are promising agroecological practices that may improve crop performance while reducing external inputs. This research evaluated the effects of dead and living mulching on weed suppression, soil moisture, and grain yield in three grain legume species. A field experiment was conducted in 2025 at S.S. Briga (38°06'43" N, 15°09'46 E, 155 m a.s.l.), Messina, northeastern Sicily, Italy. The experiment was arranged in a split-plot randomized block design with three replications. Inter-row soil management was assigned to main plots, while legume species were assigned to sub-plots. Each sub-plot measured 6 m² (2 × 3 m), resulting in a total net experimental area of 90 m². Four inter-row soil management treatments were compared: hand weeding (HW; performed twice at early May and June), living mulching with *Trifolium subterraneum* (SubM; 35 kg/ha seed rate), dead mulching with wheat straw (StrawM; approximately 10 cm thick), and a control without weed management. Three neglected ecotypes of chickpea, lentil, and grasspea were hand-sown on 9 January 2025 at 5 cm within rows and 70 cm between rows. Crops were harvested manually on 26 June 2025 at full grain maturity. Soil moisture (20 cm depth, measured on 7 May 2025), weed biomass at harvest, and grain yield were assessed on a 1-m linear basis. Data were analyzed by two-way ANOVA, and means were separated by Tukey's HSD ($p \leq 0.05$). A significant interaction between legume species and inter-row soil management was detected for all measured variables. Averaged across species, StrawM significantly increased soil moisture compared with the control (24% vs. 9%), followed by SubM (20%), and this increase was consistent across the three species (Figure 1). Similar trends were observed in all three grain legumes. At the same time, StrawM and SubM markedly reduced weed biomass relative to control (15 and 13 vs. 70 g dry weight m⁻², respectively), with a similar pattern among legume species. Improved soil water availability and weed suppression translated into higher grain yields. Average yield was greater under StrawM and SubM than HW (1.0, 0.9 and 0.7 t ha⁻¹, respectively), whereas the absence of weed control reduced grain yield by 87% on average. Chickpea

and grasspea achieved their highest grain yields under StrawM, while lentil performed best under SubM. Both wheat straw and *T. subterraneum* mulching effectively enhanced soil moisture, suppressed weeds, and increased grain yield in grain legumes. These practices represent promising agroecological alternatives to intensive tillage and synthetic herbicides. Further study is needed to evaluate their effectiveness across a wider range of grain legume species and pedo-climatic conditions.

A multidisciplinary approach to evaluate salt tolerance in tomato

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Session: 3. RI-PROGETTAZIONE

Presentation: Poster

Soil salinity is a major abiotic stress limiting crop productivity worldwide and posing a significant threat to food security. PRIN2022PNRR “TomResAMed” project aims to improve salt tolerance in tomato by identifying and exploiting genetic diversity at Glutathione S-transferase loci. A non-redundant reference core collection of 50 *Solanum l. var. cerasiforme* genotypes was established to generate a comprehensive catalogue of GST allelic diversity, referred to as the tomato pan-GSTome. This catalogue was developed through target sequence enrichment combined with third-generation sequencing. To investigate the functional relevance of sequence variation at GST loci, we integrated, field experiments, high-throughput plant phenotyping (HTTP), comparative RNA-seq transcriptomics and CRISPR/Cas9-edited mutants. In 2024, the core collection was evaluated under field conditions using different salinity levels, corresponding to 5, 10 and 20 dS m⁻¹. This experiment allowed the classification of genotypes according to their eco-physiological and productive responses to salt stress. Principal component analysis of yield-related traits enabled the identification of contrasting responses in terms of productivity and salt tolerance. In particular, genotypes 28, 36, 39, 42 and 43 emerged as candidate accessions combining relatively high yield under saline conditions (Fig. 1). Further investigation during the 2025 season at the ALSIA Basilicata PhenoLab 4.0 platform, a HTTP plant phenotyping infrastructure dedicated to the non-invasive analysis of plant traits and stress responses. The evaluation of multiple eco-physiological and productive parameters provided a deeper characterization of salinity tolerance within the collection. The results confirmed genotype 36 as one of the most promising genetic resources and in addition genotypes 06 and 47 (Fig. 2). Overall, our results indicate that salt tolerance in tomato is a complex and heterogeneous trait, arising from coordinated physiological and molecular responses rather than from a single adaptive mechanism. Tolerant genotypes, including 36, 06 and 47, maintained higher NDVI values and showed a lower Senescence Index under high salinity, indicating delayed chlorophyll degradation and improved canopy stability. In addition, tolerant accessions displayed a more efficient regulation of gas exchange, with coordinated reductions in stomatal conductance and transpiration that supported water-use efficiency while limiting losses in photochemical performance. Transcriptomic analyses revealed a major role for GST-mediated redox homeostasis. In particular, salt tolerance in 36 was associated with the upregulation of specific lambda- and phi-class GST genes, including a lambda GST located on chromosome 10. These genes may contribute to reactive oxygen species detoxification

through antioxidant enzymes such as glutathione peroxidase and ascorbate peroxidase, while supporting chloroplast redox balance through the NTRC and Fd-TRX systems. Moreover, tolerance was associated with enhanced source-sink coordination, including the upregulation of genes involved in sucrose unloading and cell wall remodelling in fruits, suggesting the maintenance of carbon allocation to reproductive organs under osmotic stress (Fig. 3). In conclusion, TomResAMed provides a detailed characterization of the tomato pan-GSTome and proposes an integrated functional model of salinity tolerance involving redox balance, photosynthetic regulation. The identification of promising salt-tolerant genotypes, particularly 36, together with additional high-performing accessions such as 06 and 47, provides valuable genetic resources and molecular targets for breeding climate-resilient tomato varieties.

Maize productivity under low-N input: a modelling approach to a future climate scenarios in Malawi

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Abstract ID: 292

Session: 3. RI-PROGETTAZIONE

Presentation: Poster

In Malawi, about 5.4 million people in rural and secondary urban communities experience moderate to severe chronic food insecurity. Limited access to agricultural inputs and financial resources constrains smallholder farmers' ability to maintain maize production under low nitrogen-input conditions. Climate change is projected to exacerbate the fragility of these systems, increasing yield variability and undermining food security. This study aims to assess the effects of future climate on maize yields under business-as-usual management as a basis for developing adaptation pathways. Field data were gathered from trials conducted across five Agricultural Extension Planning Areas in Malawi (Karonga, Machinga, Nkhatabay, Rumphi, and Zomba) in 2020-2021. Maize (cv. SC-537) was cultivated under three N fertilization systems: full inorganic (IN, 92 kg ha⁻¹ of N), full organic (OR, 3 Mg ha⁻¹ of manure), and a combination of organic and inorganic (CO, 46 kg ha⁻¹ of N + 1.5 Mg ha⁻¹ of manure). Data on soil, management, phenology, and crop yields were collected. Alongside, semi-structured interviews were conducted with farmers and staff from the Ministry of Agriculture to co-design a scenario analysis that includes low-N-input fertilization strategies, reflecting the prevailing conditions of a subsistence farming system. The CERES-Maize model, provided by the Decision Support System for Agrotechnology Transfer (DSSAT v4.8), was used to run simulations. Long-term climate projections were used for scenario analysis, comparing two future periods (2015–2044; 2045–2074) with a baseline (1985–2014). Daily outputs from five General Circulation Models (GCMs: GFDL, IPSL, MPI, MRI, UKES) were applied under three Shared Socioeconomic Pathways (SSP1-2.6, SSP3-7.0, SSP5-8.5). The baseline was generated from the ISIMIP (CMIP6) historical climate dataset, projected by the same GCMs and bias-corrected to match local observations. Model calibration with the Rumphi IN dataset showed good agreement between observed and simulated data. Emergence and maturity dates were reproduced within 1–4 days of observations. The observed grain yield was 8.85 Mg ha⁻¹ of DM, whereas the simulated average yield was 10.08 Mg ha⁻¹ of DM. The standard deviation of the observed yield was 1.84 Mg ha⁻¹ of DM; hence, the simulated value was within the confidence interval of the observed data. Model evaluation across sites and treatments confirmed the robustness of the calibration. A good agreement was observed between the observed and simulated yields ($R^2 = 0.82$), with a low prediction error (RMSE = 1.25 Mg ha⁻¹ of DM; CV(RMSE) = 0.19%) and

a high index of agreement ($D = 0.94$). The local agroecological conditions affected the responses to the fertilization strategies across sites (Fig. 1). Climate projections in all stations indicated rising temperatures and changes in precipitation patterns. Overall, yield stabilization rather than yield declines were observed under future scenarios. Combined and inorganic fertilization treatments showed greater resilience and higher productivity under future climate scenarios than baseline, whereas the organic strategy was more sensitive to warming, especially in southern sites. These findings suggest that combined fertilization represents an adaptation strategy that offers yields comparable to those of inorganic fertilization while improving accessibility for smallholder farmers.

Plant-insect sodium asymmetry: a sustainable approach for phytophagous control in agriculture

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Abstract ID: 296

Session: 3. RI-PROGETTAZIONE

Presentation: Poster

Crop losses caused by pests and diseases account for approximately 40% of annual global crop production, with major consequences for food security. In tomato, phytophagous insects are responsible for 3,4% of annual yield losses and may represent 5-12% of the total cost of tomato production. Moreover, climate warming is expected to exacerbate insect pressure by increasing the number of generations metabolic rate and feeding activity. Therefore, sustainable strategies aimed at enhancing crop tolerance or resistance to phytophagous damage are needed. Here, we propose that the asymmetry in sodium requirements between plants and insects may represent a novel and exploitable mechanism for pest control in tomato. While plants generally require sodium only in trace amounts, sodium is essential for herbivores, including insects, because of its central role in osmoregulation, excretion and neural activity. This biological relevance has led sodium to be defined as the “seventh macronutrient” for herbivores. Previous studies suggest that plants may modulate their ionome as an escape strategy to reduce leaf palatability to phytophagous insects. Building on this concept, our project aims to investigate whether sodium homeostasis in tomato can be manipulated or selected to enhance tolerance to insect damage. The project is structured around three main objectives: i) investigating the cascading effects of sodium content in plants on higher trophic levels; ii) elucidation of the mechanisms through which plants modulate sodium content in their tissue in response to insect attack, iii) identifying novel breeding strategies and tools for enhancing plant defense. The first objective will define the minimum sodium requirements for herbivore diets and assess their effects on larval microbiota, immunity and fitness. Reduced sodium availability may impair insect immune responses, potentially increasing the effectiveness of classical biological control agents. The second objective will clarify the mechanisms underlying insect-induced sodium redistribution in tomato tissues, providing useful knowledge for the development of varieties with improved tolerance to herbivore attacks. Finally, sodium variability will be evaluated in a collection of tomato genotypes, followed by open-field trials comparing varieties with sub-optimal, optimal and supra-optimal sodium levels for larval growth and fitness. If confirmed, this hypothesis will allow the identification of a novel trait of tolerance to insect attacks in tomato that could be functionalized to reduce the need for insecticides for plant protection. This will be obtained thanks

to the identification of phytophagous tolerant-varieties or development of new varieties via gene editing technology.

Seed Quality, Imbibition Dynamics and Species Compatibility in Multi-Species Hydroponic Fodder Systems

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Abstract ID: 297

Session: 3. RI-PROGETTAZIONE

Presentation: Poster

Background. Hydroponic fodder systems provide fresh and highly digestible forage under controlled, soil-free conditions while minimizing water consumption. Barley (*Hordeum vulgare* L.) is the most widely adopted species because of its rapid germination and vigorous early growth; however, hydroponic barley fodder is often characterized by low protein concentration and high moisture content. Integrating cereals with legumes and pasture grasses may improve forage quality. Nevertheless, successful multi-species cultivation requires compatible germination behaviour, synchronized water uptake and effective seed disinfection. **Objective.** This study evaluated germination performance, biometric traits and imbibition dynamics of thirteen forage species belonging to three functional groups: cereals (*Avena sativa* L., *Hordeum vulgare* L., *Secale cereale* L. and *Triticum aestivum* L.), legumes (*Crotalaria juncea* L., *Onobrychis viciifolia* Scop., *Pisum sativum* L., *Trifolium pratense* L. and *Vicia sativa* L.) and pasture grasses (*Dactylis glomerata* L., *Festuca arundinacea* Schreb., *Lolium perenne* L. and *Phleum pratense* L.). The effects of sodium hypochlorite (NaClO; 0, 0.5, 1.5 and 2.5%) on germination and seedling development were also assessed. Germination tests were conducted under controlled conditions according to International Seed Testing Association procedures. Germination percentage, seedling growth and vigor parameters were determined. Species-specific water uptake dynamics were characterized through 24-h imbibition curve analysis. Three parameters were derived: imbibition rate at plateau onset, percentage of maximum absorption at plateau and maximum water uptake relative to initial seed dry weight. Data were analysed using two-way ANOVA (species $\times$ NaClO concentration), followed by Student–Newman–Keuls post-hoc test ($P \leq 0.05$). Marked interspecific differences in germination and imbibition behaviour were observed among functional groups. Among cereals, *H. vulgare* exhibited the highest germination percentage and seedling vigor, confirming its suitability as the main component of hydroponic mixtures. Legumes showed the greatest water uptake capacity, whereas *P. sativum*, *V. sativa* and *O. viciifolia* displayed the highest compatibility with cereals, reaching the imbibition plateau within 5–6 h. Among pasture grasses, *L. perenne* emerged as the most suitable species, exhibiting the earliest plateau (2 h) and the lowest maximum absorption (91.9%). Increasing NaClO concentrations significantly reduced germination in most species, with pasture grasses being the most sensitive group, whereas cereals showed greater tolerance. Significant species and treatment effects were detected for the main germination traits. Species selection strongly influences the feasibility of multi-species hydroponic fodder systems. *H. vulgare*, combined with

selected legumes such as *P. sativum*, *V. sativa* and *O. viciifolia*, represents a promising strategy for improving forage quality. Optimizing seed disinfection protocols and selecting species with compatible imbibition kinetics are essential for developing nutritionally balanced and sustainable hydroponic fodder systems.

From Participatory Nitrogen Research to Hedgerow-Based Forested Infiltration Areas: Twenty Years of Co-Designed Solutions in a Mediterranean Nitrate Vulnerable Zone

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Session: 3. RI-PROGETTAZIONE

Presentation: Poster

The Arborea district (Sardinia, Italy) is one of the most productive and environmentally pressured Mediterranean Nitrate Vulnerable Zones, where intensive dairy farming has generated persistent groundwater nitrate contamination despite nearly two decades of mandatory action programmes under EU Nitrates Directive 91/676/EEC. Apparent nitrogen surpluses reaching $500 \text{ kg ha}^{-1} \text{ y}^{-1}$, driven largely by massive soybean flour imports, have proven structurally resistant to standard top-down mitigation approaches. Over twenty years, our research team engaged this challenge through a long-term participatory pathway that progressively reframed nitrogen dynamics not as a technical problem but as a socio-ecological learning system, co-navigated with farmers, cooperatives, and local institutions. Successive projects revealed that sustainable N management requires integrated portfolios combining precision fertilization, animal effluent reuse, and adaptive governance, and that co-design itself generates irreplaceable epistemic and social capital. Within this trajectory, the current research phase explores the potential of existing agroforestry elements, hedgerows and woodlots already embedded in the Arborea landscape, as Nature-Based Solutions to accelerate in-situ denitrification. Eucalyptus hedgerows occupy approximately 3-5% of the agricultural surface within the Arborea Nitrate Vulnerable Zone, corresponding, based on photointerpretation estimates, to a total area of 215-255 ha and an aggregate hedgerow length of 265-315 km. This hypothesis draws on original data from a pilot Forested Infiltration Area (FIA) implemented at Luri, a locality within the Arborea municipality where a dewatering pumping station supplies nitrate-rich drainage water ($70\text{-}80 \text{ mg L}^{-1} \text{ NO}_3^-$) to the system. The water is conveyed through six recharge trenches (total length 300 m, depth 1 m) filled with a Permeable Reactive Barrier of eucalyptus woodchips, clay, and

iron oxides, stimulating denitrifying bacteria that convert NO_3^- to N_2 . Three years of hydrogeochemical monitoring document a 60-80% reduction in groundwater nitrate recharge concentrations relative to input water, with negligible nitrite, ammonium, or N_2O production, and monitoring wells consistently below the EU threshold of 50 mg L^{-1} . These results establish a proof of concept for FIA-based remediation in agricultural lowlands. Scaling this approach to the Arborea hedgerow network raises three interconnected research questions currently driving our fieldwork. First, how can FIA behaviour, designed for engineered trenches, be modelled and parameterised when extended to the heterogeneous geometry of existing hedgerows and riparian woodlots, in a form usable by practitioners and land planners? Second, the critical operational challenge is how to extract contaminated water from the shallow aquifer and route it through the biological reactive zone while maintaining hydrological equilibrium and sustaining denitrification efficiency, an engineering and ecological optimisation problem not yet resolved. Third, the hydrological role of existing hedgerows at the landscape scale remains systematically underestimated. To address this gap, we are conducting dedicated dendrometric surveys to estimate mean growth rates and biomass stocks, necessary inputs for partitioning evapotranspiration and interception within the catchment water balance. These lines of evidence and open questions situate hedgerow-based denitrification within the broader participatory framework developed over two decades at Arborea, linking biophysical innovation with co-designed governance for persistent nitrogen challenges in Mediterranean agriculture.

Evaluating cover crops as a sustainable soil management strategy in Mediterranean olive groves: trade-offs, drivers, barriers and ecosystem service assessment

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Session: 3. RI-PROGETTAZIONE

Presentation: Poster

Mediterranean olive groves are threatened by soil degradation, climate change, and water scarcity, while conventional tillage can intensify erosion and reduce soil functionality. Cover crops may offer a sustainable alternative, but their environmental benefits, economic implications, and social feasibility remain context dependent. This study compared cover-crop (CC) and tillage (TT) systems through an integrated framework structured into three domains: ecosystem service provision, economic performance, and social feasibility. Within the ecosystem-service domain, soil properties were assessed at five Spanish olive-grove sites, with samples collected at 0-10 and 10-30 cm depths and analysed for total nitrogen, available phosphorus, bulk density, available water, microbial gene abundance, and soil carbon stock; woody crop production indicators in terms of olive yield, estimated oil production, and pruning wood biomass were also included. Mixed-effects models and multivariate analyses evaluated management effects. Economic performance was assessed across 55 Spanish olive farms using gross margin, returns to labour, and labour intensity, while social feasibility and adoption drivers were examined through questionnaires completed by 19 olive growers. Indicators were normalized to compare multidimensional performance. Ecosystem-service responses showed substantial overlap between CC and TT, and no statistically supported management effects were detected. Descriptively, CC tended to increase topsoil nitrogen and subsoil available water, whereas TT showed higher microbial abundance and slightly greater soil carbon

stock; site-specific variability strongly influenced these patterns. Economic outcomes were similar between systems: CC farms showed numerically higher gross margins and returns to labour and lower median labour intensity, but none of these differences remained significant after multiple-testing correction. Social indicators indicated adequate knowledge of cover crops, whereas limited machinery access, perceived production risks, and weak market rewards emerged as barriers. Overall, cover crops did not consistently outperform tillage across all domains, but showed potential advantages for selected indicators without detectable penalties in olive yield or profitability.