AGRINNOVA

RESEARCH BEARS ITS FRUITS

INTERDEPARTMENTAL CENTRE OF THE

UNIVERSITY OF TORINO

REPORT OF ACTIVITIES

2024

Grugliasco, April 4, 2025

The Director

Prof. Alberto Alma

EXECUTIVE SUMMARY

In 2024, the activities of the Interdepartmental Center Agroinnova were conducted within the context of both national and international research initiatives, promoting collaborations with numerous partners and stakeholders in Italy and other countries.
Agroinnova activities are based on the following macro areas:

- Basic and Applied Research: Agroinnova is dedicated to promoting impactful research projects in the agro-environmental and agri-food fields, fostering relationships with foreign public and private stakeholders.
- Technology Transfer: Agroinnova collaborates with Italian and European industries transferring knowledge and technologies internationally.
- Communication: The Center's scientific production was communicated through scientific papers, various conferences, workshops, cultural activities, and media to reach a wider audience.

Agroinnova research focuses on the following specific areas:

- Plant Pathology and Disease Management: Biology, epidemiology, and the management of economically important crop pathogens, focusing on low-impact crop protection strategies.
- Molecular Biology: Dealing with pathogen characterization, development of diagnostic tools, and the study of pathogenesis mechanisms.
- Food Safety: Studying innovative solutions for postharvest disease and quality management and for prevention and control of mycotoxigenic fungi and mycotoxins.

Many of projects that are described in this document highlight the phytosanitary problems that develop and evolve under the current climate conditions in Italy and other countries where our partners operate. For instance, the Kiwi vine decline syndrome, a complex problem caused by concurrent biotic and abiotic factors that is affecting two thirds of the cultivated area in Piedmont is addressed by Agroinnova in two projects (SOS-KIWI and KIPOTRÁ projects). On citrus two projects (KeyPlex and Citrus Research International) explore a very serious diseases complex caused by different species of the pathogen *Colletotrichum* spp. in Europe and the USA.
In the contest of sustainability, circular health and circular economy Agroinnova is involved in several projects for reducing external inputs and improving productivity, health, quality, safety and security of crops by recycling of wastewater and other organic materials, and implementing precision agriculture systems aiming at reducing the use of fungicides to control plant diseases in different pathosystems (CH4I, ReNEWater, CHEDIH, WalNUT).
The diagnostic laboratory of Agroinnova that has been recognized as an official phytosanitary laboratory by the Regional Phytosanitary authorities engaged for the first time in a proficiency test in the area of entomology for the identification of *Bactrocera dorsalis* and *B. zonata*, fruit flies of quarantine importance. In the frame of the diagnostic research activity a qPCR was developed for the detection of the emerging pathogen *Trichoderma afroharzianum* in maize and a duplex PCR test for the detection of *Rhizoctonia solani* and *Colletotrichum coccodes* on potato. The thirty-three publications on ISI journals underline the quality of the research carried out by the scientists collaborating with Agroinnova.
Most of Agroinnova staff and collaborators are affiliated to DISAFA, but during 2024 scientists from three other university departments became collaborators of Agroinnova and we expect that, soon, more interdepartmental research activities and collaborations will widen the research focus.

RESEARCH ACTIVITY

a) Biology, epidemiology, and management of pathogens of economically important crops

Ornamentals

PROJECT: BIO-SAL. BIODIVERSITÀ E SALUTE DELLE PIANTE.

Objectives:

The purpose of this project is to promptly report new pathogens affecting ornamentals and horticultural crops to prevent their spread. Nurseries producing ornamentals, and aromatics as well as private and public gardens located in Piedmont and Liguria are monitored with the collaboration of technicians, farmers and citizens.

Results 2024:

The morphological characteristics observed *in vivo* on affected plants and/or *in vitro* on pure cultures of the isolates allowed the identification of the causal agents of the diseases. Molecular analyses carried out on pure cultures of the isolates confirmed the morphological identification. The pathogenicity of the isolates was confirmed by reproducing symptoms on healthy plants artificially inoculated with the pathogens.
Plants of *Rhododendron arboreum* hybrids (Ericaceae), grown in a private garden located in Campiglia Cervo (Biella province, northern Italy) showed well defined, irregular, brown, necrotic spots with chlorotic haloes on the basal leaves. In the presence of high atmospheric humidity, leaf symptoms spread and caused a soft rot on the affected tissues. These symptoms were ascribable to *Botrytis cinerea*. In the same garden, some plants of *Viburnum opulus* showed brown spots that expanded on a large part of leaves causing irregular necrosis with no clear margins. The affected tissues dried, and the aesthetic value of the plants was compromised. The morphological characteristics were compatible with those of *Diaporthe eres*. In a nursery located in Ventimiglia (Imperia province), symptoms of soft black rot were detected at the top of the stems of *Polaskia chichipe* (Cactaceae. Symptoms and characteristics observed both *in vivo* and *in vitro* were typical of *Bipolaris cactivora* (Syn.: *Drechslera cactivora* and *Helmintosporium cactivorum*). In the same nursery, symptoms of stem rot were observed on *Echinopsis gemmata* and *Mammillaria spinosissima crestata*, both belonging to the Cactaceae family. Several plants of *E. gemmata* showed brown discolorations on stems that wilted, collapsed and showed a soft rot of the internal tissues at collar level. The disease caused the death of the affected plants. Whitish to pale purple fungal colonies were isolated from affected internal tissues of the collar. The morphological characteristics were recognized as typical of *Fusarium oxysporum*, probably belonging to the *forma specialis opuntiarum*, very common on species belonging to the Cactaceae family. Stems of *M. spinosissima crestata* showed external necrosis and drying, corresponding to internal rotted tissues. The internal collar tissues were also rotted. Pale pink to reddish fungal colonies were isolated from internal tissues of both the stem and the collar. Colonies produced structures typical of *F. oxysporum*. *Stagonosporopsis trachelii* (Syn.: *Phoma trachelii* and *Ascochyta bohemica*) was detected in Italy on *Campanula rapunculoides*, *C. medium* and *C. trachelium*. The pathogen was detected also on seed of *C. rapunculoides* and *C. trachelium* seeds.

Publications on ISI journal:
Annex V, publications no. 6,7, 8

Other publications: Annex V, publications no.35, 36, 37, 56

Vegetables and Officinal species

PROJECT: CHARACTERIZATION OF *PERONOSPORA BELBAHRII* POPULATIONS CULTIVARS OF KNOWN SUSCEPTIBILITY OR DECLARED AS TOLERANT/RESISTANT.

Objectives:

Peronospora belbahrii, causal agent of downy mildew of basil, is currently the most serious foliar pathogen of basil. Great interest is posed to monitoring the behavior of the pathogen populations in the cultivation area of basil considering the risk of selecting populations of the pathogen resistant to fungicides and the possible evolution of the pathogen into races capable of overcoming the main resistance genes of *Ocimum basilicum* genotype, as occurred in Israel and New Jersey on basil cv. Prospera.

Results 2024: Populations of the pathogen were collected from the main production areas in Veneto, Emilia Romagna and Piedmont from the field or from propagation material. A dataset with the main information related to each population was determined. A collection of 14 genotypes (cultivated and breeding lines) of basil were tested for basil downy mildew resistance to define a set of differential cultivars in relation to the susceptibility of tolerant/resistant cultivars and the interaction with the pathogen. Twenty out of the 40 pathogen, *P. belbahrii* , populations tested in the greenhouse and in growth chamber under conditions favorable to the pathogen (18-26°C and > 80% relative humidity) showed different levels of aggressiveness compared to the reference population of the pathogen. Under controlled inoculation conditions the cv. Prospera resulted partially resistance but not immune to many of the population of the pathogen tested, not allowing an explanation for the loss of performance in 2022. Cultivars with different susceptibility to the pathogen have been identified depending on disease pressure: cv. Eleonora, Zeus and Prospera were resistant, Lemon and Red Rubin are partially resistant, Garibaldi and Gervaso are moderately susceptible while Italiko is very susceptible. Some of the tested improved cultivars for pathogen tolerance showed symptoms of slight hypersensitivity reactions or are responsible for plant defoliation. Particular attention should be put on the pathogen populations obtained from infected seeds; one out of 8 was different from the reference population. The monitoring conducted in the field showed the presence of emerging foliar pathogens that are under characterization. Also soilborne pathogens like *Rhizoctonia solani* and *Fusarium oxysporum* f.sp. *basilici* must be monitored.

Other publications: Annex 5, publications no. 44, 47.

PROJECT: PHYTOSANITARY STATUS OF OFFICINAL SPECIES IN PIEDMONT: IDENTIFICATION OF THE CAUSAL AGENTS AND ASSESSMENT OF SEED AND OF PROPAGATION MATERIAL HEALTH (COOPERATIVA ERBE AROMATICHE PANCALIERI - CEAP)

Objectives: The research project aimed to investigate the phytosanitary status of officinal herbs cultivated in Piedmont, with a focus on those of interest to *Artemisia* spp. and *Satureja hortensis*. The objectives were: i) to identify the causal agents of diseases of officinal herbs in Piedmont; ii) to assess the phytosanitary condition of seed and propagation material of the officinal species used by the Cooperative for the establishment of new field crops.

Results 2024: The study showed the presence of several fungal pathogens associated with different diseases: *Fusarium spp.*, *Rhizoctonia solani*, isolates of the families *Botryosphaeriaceae* and *Diaporthaceae* were frequently isolated from symptomatic plants of *Artemisia* spp., while *Alternaria* spp. was identified as the primary agent of leaf diseases in *Satureja hortensis*. Soilborne pathogens such as *Verticillium dahliae* and *Fusarium* spp. were

confirmed through molecular analyses and were found to be responsible for vascular discoloration, root rot, and plant wilting, particularly in *Artemisia pontica* and *Artemisia absinthium*. Seed health testing highlighted significant contamination, with bacterial and fungal infections detected across different seed lots of *Satureja hortensis*. High levels of *Alternaria spp.*, *Cladosporium* spp., and *Fusarium* spp. were recorded, with notable variations among samples. Some seed lots showed a high prevalence of fungal infections, while others were more affected by bacterial contamination. Additional testing on seedlings grown in sterile sand confirmed the presence of seed-transmitted pathogens, particularly *Fusarium* spp. and *Verticillium* spp., which caused root browning and compromised seedling development. Pathogenicity tests further validated the virulence of *Alternaria* spp. and *Verticillium dahliae*, demonstrating their ability to induce symptoms like those observed in the field. The results underlined the importance of monitoring the health status of both plants and seed to prevent the spread of fungal diseases and ensure the production of healthy propagation material.

Kiwifruit

PROJECT: FROM SOIL TO SOIL: ORIGIN AND REMEDIATION TO KIWIFRUIT VINE DECLINE SYNDROME (SOS-KIWI)

Objectives: the project aims at investigating a multifactorial plant disease using Kiwifruit Vine Decline Syndrome (KVDS) as a model, dissecting the mechanisms behind this complex syndrome, and identifying biomarkers and prevention and control strategies that can be used to contrast its spread and to improve plant health. To achieve this overall goal, six main objectives are identified: 1) identify biotic and abiotic factors associated with KVDS; 2) dissect the mechanisms behind the induction of KVDS; 3) evaluate Actinidia germplasm resources; 4) design prevention and control strategies; 5) develop microbial consortia with plant growth stimulation features; 6) transfer the project results to the field and analyze their technological, socio-economic and environmental impact. Besides helping in closing the knowledge gap on KVDS, and helping to understand better the plant microbiome, this project will also generate molecular tools to quickly diagnose KVDS, high quality propagation material, rootstocks adapted to KVDS inducing soils, biofumigation protocols, and prototype formulations of microbial consortia with biocontrol and plant growth stimulation features. This integrated approach will provide effective tools for diagnosing, preventing, and managing KVDS, ensuring sustainable kiwifruit production.

Collaborations:

- University of Udine
- University of Mediterranean Studies of Reggio Calabria
- University of Napoli Federico II
- AGRION Foundation

Results 2024: Field surveys and microbiological analyses were conducted to investigate kiwifruit decline. Soil and root samples were collected from affected orchards, and molecular techniques such as metabarcoding and PCR were used. Isolation trials confirmed the presence of *Phytophthora sojae*-like through baiting methods and molecular identification. Further characterization is ongoing, with sequencing molecular markers like TEF-1A, and specific primers are being designed for detection.

The role of biotic factors in root dysbiosis is under investigation, with plans to establish synthetic microbial communities (SynComm) for pathogenicity trials by late 2025. Molecular diagnostic tools have been developed, including a detection method for *Phytopythium vexans*, now available for use. Amplicon metagenomics studies were conducted from March to

November 2024, analyzing soil and root samples from symptomatic and asymptomatic kiwifruit plants across different regions. DNA extraction methods were optimized, and future studies will focus on symptom-based plant selection and standardized extractions for comparative analyses.
Protocols for in vitro regeneration of potential kiwifruit rootstocks were established. Results showed moderate propagation success for *Actinidia macrosperma* and low success for *A. valvata* in-house, while external propagation services achieved good results for both. Interspecific genotype propagation via cuttings was highly successful, and a subset of plants will undergo resistance/susceptibility screening. Gene expression analyses in grafted plants identified a preliminary set of stress-related genes, with further trials and histological analyses underway.
Nursery material was sampled at various growth stages for molecular analyses. Microbial consortia with biocontrol potential were tested in vitro against key pathogens, with selected *Pseudomonas* strains showing strong inhibition. Greenhouse trials with bacterial and fungal biocontrol agents, as well as soil amendments, had diverse effects on plant growth and root health. Vermicompost and certain microbial treatments improved shoot growth, while phosphite applications caused the least root damage. Further isolations and compatibility assessments will refine microbial consortia development.
Soil biofumigation trials with rocket plant extracts showed promising results in reducing root damage and pathogen presence. Higher extract dosages and green manure incorporation led to lower pathogen levels in the rhizosphere, with field feasibility trials under consideration. Microbial consortia with plant growth-promoting properties were selected based on compatibility and beneficial traits, with two arbuscular mycorrhizal fungi strains added to enhance their effectiveness. Greenhouse trials assessing plant growth-promoting rhizobacteria activity under different soil conditions need to be repeated due to temperature anomalies during the initial experiment.

Publications on ISI journal: Appendix V, publications no. 12, 19.

PROJECT: KIWIFRUIT VINE DECLINE SYNDROME – EVALUATION OF THE USE OF INNOVATIVE ROOTSTOCKS AS AN AGRONOMIC STRATEGY TO PREVENT SYMPTOM DEVELOPMENT (KIPOTRÁ)

Objectives: This project continues the activities started with the KIRIS project, which concluded in 2023, to further investigate rootstocks as a strategy for preventing Kiwifruit Vine Decline Syndrome.
In Piedmont, where the total kiwi cultivation area covers 3.128 ha, only about 1.000 ha remains productive, indicating a critical situation for this important regional crop. Over the past three years, the KIRIS project has investigated the origins of the syndrome and tested agronomic techniques to mitigate symptom development. To prevent and mitigate the disease, several rootstocks showed promising resistance under experimental and field conditions, but further validation is needed. This project will evaluate new kiwi rootstocks (*Z1, Bounty 71, Yanoon*) through biometric surveys and qualitative-quantitative production analyses in recently established orchards. An experimental trial on self-rooted *Hayward* kiwi will test natural products like kaolin and *Syneco AF5* to mitigate climate stress. Physiological assessments will measure key parameters, including photosynthetic activity, stomatal conductance, and transpiration. Pathological analyses will focus on plant, soil, and root pathogens through classical isolation and molecular identification, while also examining the root microbiome of the evaluated rootstocks. The collected data will be analysed and shared with stakeholders through technical meetings and potential scientific publications, offering valuable insights for the future of kiwi cultivation.

Collaborations:

- AGRION Foundation
- Phytosanitary Sector of the Piedmont Region

Results 2024: Agroinnova analysed symptomatic plant material collected both in diseased and healthy orchards, investigating the microbiome of roots, rhizosphere, and soil to identify microorganisms associated with Kiwifruit Vine Decline Syndrome. Additionally, a molecular diagnostic assay was developed for detecting *Phytopythium vexans*.
Isolation trials confirmed the presence of *P. vexans* in symptomatic samples, while microbiome analysis revealed rhizosphere dysbiosis in diseased plants, characterized by microbial community shifts. Notably, oomycetes of the *Phytopythium* genus were predominant in diseased samples, although also present in healthy ones. Metabarcoding analysis established a significant correlation between *Phytopythium* abundance and symptomatic plants, highlighting quantitative differences between healthy and affected orchards. Bacterial and fungal communities exhibited high diversity, with site- and matrix-dependent variations. Network association analysis suggested potential competition among oomycetes, bacteria, and saprobes for plant-derived carbon. *Phytopythium* showed negative correlations with mycorrhizal fungi and root growth-promoting species.
For the diagnostic assay, species-specific primers targeting the mitochondrial *COI* gene were designed, and a SYBR Green-based qPCR Real-Time assay was developed. Validation followed EPPO PM7/98 international standards. The qPCR assay demonstrated high sensitivity in detecting and quantifying *P. vexans* in both artificially inoculated and naturally infected samples.

Publications on ISI journal: Appendix V, publications no. 13.

PROJECT: EFFICACY OF PREBIOTICS AND PROBIOTICS IN THE CONTROL OF KIWIFRUIT VINE DECLINE SYNDROME (BIOLCHIM S.P.A.)

Objectives: The research aimed to evaluate the efficacy of prebiotic and probiotic treatments in mitigating Kiwifruit Vine Decline Syndrome. By conducting field trials in two orchards with different disease incidence levels, the study analyzed the effects of these treatments on soil microbiota and plant health. Rhizosphere samples were collected before flowering and after harvest, and metabarcoding sequencing was used to identify changes in bacterial, fungal, and oomycete populations.

Results 2024: The two treatment strategies applied in orchards with different syndrome incidence showed differences in diseases incidence and severity. High doses of prebiotic and probiotic (treatment 1) in an orchard with severe vine decline, did not effectively reduce disease incidence. However, it resulted in higher chlorophyll content in treated plants compared to other conditions. On the other hand, prebiotic and probiotic applied at lower doses (treatment 2) in an orchard with milder disease symptoms, contributed to a slight reduction in disease incidence over time, although the effect was not significant. Metabarcoding analysis revealed inconsistent effects of the treatments on the microbial community. Both treatments led to an increased presence of beneficial bacterial genera, particularly *Bradyrhizobium*, known for its role in nitrogen fixation, carbon sequestration under anaerobic conditions, and nitrogen nitrification. Similarly, *Rhodoplanes*, another nitrogen-fixing genus, was more abundant in treatment 1 and is associated with improved microbial quality soil. However, both treatments resulted in a decline of *Flavobacterium* and *Bacillus*, genera typically considered beneficial in soil communities. Fungal populations did not show significant changes in response to the treatments. However, in the second orchard, the second

sampling revealed a greater presence of plant-pathogenic fungi, including *Berkeleyomyces*, identified as the causal agent of black root rot. The treatments also had no significant effect on oomycete populations, with *Phytopythium,* particularly *Phytopythium vexans,* remaining consistently present, confirming its role as a major contributor to Kiwifruit Vine Decline Syndrome. Overall, the results suggest that Treatment 2 in the orchard with lower disease incidence could improve soil microbial composition by increasing beneficial soil taxa, but its impact on disease progression was only partial. No phytotoxic effects were observed at either dosage tested.

Cereals

PROJECT: INTEGRATED APPROACH TO THE MANAGEMENT OF BAKANAE AND BLAST DISEASES IN RICE (SA.PI.SE - SARDO PIEMONTESE SEMENTI SOC. COOP.)

Objectives: The study aimed at identifying pathogenicity effectors in different Italian subpopulations of *Pyricularia oryzae* and to evaluate the effectiveness of seed coating treatments on rice caryopses naturally infected with *Fusarium fujikuroi*. The research focused on monitoring *P. oryzae* by isolating strains from naturally infected rice plants in SA.PI.SE. experimental fields and assessing *F. fujikuroi* management through incubation tests, greenhouse trials, and molecular diagnostics.

Results 2024: Rice samples affected by blast disease were provided by SA.PI.SE. The pathogen, *Pyricularia oryzae*, strains were isolated through single-conidial isolation. A total of 30 morphologically distinct isolates were obtained from the 22 samples provided. Molecular characterization of these isolates involved total DNA extraction and identification using specific primers. Positive strains were analyzed through microsatellite region amplification to evaluate their genetic diversity and determine their affiliation with different Italian subpopulations of the pathogen.
Experimental activities were conducted to assess seed coating treatments efficacy against *F. fujikuroi,* causal agent of bakanae disease of rice. The study included laboratory *in vitro* tests and greenhouse trials, examining the susceptibility of different rice varieties to the pathogen and quantifying its presence in rice seeds using LAMP and real-time PCR techniques. The seed treatments tested included a chemical fungicide (Fludioxonil, used as the reference), a physical treatment combining high-temperature steam and ultrasound (Steam Test), and a biological treatment with natural extracts and yeast-derived compounds (Seedex). Trials were conducted on the rice varieties Carnise and Unico. Laboratory *in vitro* tests showed that all treatments significantly reduced *F. fujikuroi* infection incidence compared to untreated seeds, which showed 5% to 9% infection. The Steam Test and Seedex treatments demonstrated infection incidence of 1.5% to 2.25%, comparable to the chemical treatment with Fludioxonil (1% to 1.25%). Greenhouse trials further evaluated seed germination and disease severity over four weeks. Untreated seeds exhibited 91–100% germination, Fludioxonil-treated seeds showed 94% to 98%, and Seedex-treated seeds ranged from 90% to 97%. While the Steam Test effectively reduced disease severity and incidence, it negatively impacted germination (85% to 92%). Seedex provided intermediate results, showing effectiveness in Carnise but not in Unico.
A separate experiment assessed the tolerance of 19 rice varieties to *F. fujikuroi*. The study identified Oceano, Unico, S18042, S19026, S19048, and S19067-1 as the most tolerant varieties, whereas Carnise, Ermes, S17023, and S20054 were the most susceptible. Disease severity varied significantly among the varieties, with Oceano and Unico showing the lowest severity scores, while Carnise and Ermes had the highest. Among new breeding lines, S19048 and S19067-1 showed high tolerance, suggesting potential for breeding programs to develop

resistant rice cultivars. Molecular detection methods, including real-time PCR and LAMP, were employed to analyze 12 seed batches from two rice varieties. The study found that Unico seeds from naturally infected batches had the highest fungal DNA concentrations, while Carnise seeds showed inconsistent infection levels. Commercial seed batches of Unico also exhibited the highest contamination rates. The LAMP technique demonstrated high sensitivity, identifying *F. fujikuroi* even in samples that tested negative with qPCR. Overall, the research highlighted that Fludioxonil remains the most effective seed treatment. However, alternative methods such as Seedex and the Steam Test present promising sustainable options. The identification of tolerant rice varieties offers valuable insights for breeding resistant cultivars. Moreover, the integration of molecular diagnostics, particularly LAMP, supports effective monitoring of fungal contamination in rice seeds. An integrated approach that combines resistant varieties, alternative seed treatments, and molecular diagnostics to effectively manage *F. fujikuroi* in rice production is a winning strategy to control the disease.

Other publications: Annex V, publication no. 38.

PROJECT: SUSCEPTIBILITY OF RICE TO *FUSARUM FUJIKUROI* (SA.PI.SE - SARDO PIEMONTESE SEMENTI SOC. COOP.)

Objectives: The objective of the activity was the validation of a variety susceptibility screening method on rice plants against *Fusarium fujikuroi* under controlled conditions that could be predictive of the behavior observed in the field.

Results 2024: A screening method for assessing rice variety susceptibility to *Fusarium fujikuroi* under controlled conditions was validated with the goal of predicting field behavior. In 2024, three *F. fujikuroi* strains (I1.3, Augusto2 and A5) were used for artificial inoculation. Sixteen rice genotypes were provided by SA.PI.SE., including the susceptible Carnise and moderately susceptible Oceano as controls. Two independent trials were conducted, each testing seven genotypes in triplicate, with seeds planted in a sterilized substrate under controlled environmental conditions. A conidial suspension was applied to the soil, and plant germination rates and disease severity were recorded over 28 days.
Data analysis using McKinney's formula and ANOVA revealed significant differences in germination rates. In Trial 1, line S17023 exhibited significantly lower germination in the inoculated condition (48.8%) compared to the non-inoculated control (73.3%). In Trial 2, a significant reduction in germination was observed only for S18052 in the inoculated condition (70%), while its non-inoculated control remained like other genotypes (86.6%). Other tested genotypes showed germination rates between 82.2–100% (Trial 1) and 84.4–100% (Trial 2), irrespective of inoculation. Disease severity analysis confirmed that Carnise and Oceano exhibited low and moderate tolerance to *F. fujikuroi*, with severities of 49.2% and 31.1%, respectively, aligning with previous trials. In Trial 1, S17023 and G02220 were the most susceptible, while genotypes such as G00773, S18042, S18013, and G01422 showed moderate susceptibility. G00194 emerged as the most tolerant genotype. In Trial 2, S18052 and S20054 were the most susceptible, whereas S19067-1 and S19048 exhibited the highest tolerance. Overall, S17023 and S18052 demonstrated the highest susceptibility, with reduced germination and high disease severity, whereas G00194, S19067-1, and S19048 emerged as the most promising tolerant genotypes.

PROJECT: EVALUATION OF THE EFFICACY OF PLANT PROTECTION PRODUCTS FOR THE CONTROL OF *FUSARIUM FUJIKUROI* ON RICE SEEDS (XEDA INTERNATIONAL SAS)

Objectives: The aim of the project was to evaluate the efficacy of commercial plant protection products (PPPs) applied as seed dressing against rice bakanae disease, caused by *Fusarium fujikuroi*.

Results 2024: Seeds of two rice cultivars, Carnise and Oceano (harvest 2023), were used in the study, respectively classified as susceptible and moderately susceptible to bakanae disease. *Fusarium fujikuroi* strain A5 was selected for artificial seed inoculation based on its confirmed virulence. Disinfected seeds were immerged in a conidial suspension of the pathogen for 30 minutes under agitation, followed by drying on sterile filter paper under a laminar flow hood for 30–60 minutes. Sed dressing treatments with plant protection products (PPPs) provided by XEDA were applied by dipping the seeds in aqueous suspensions for 30 minutes. The experimental setup included a healthy control, an inoculated untreated control, and a chemical control treated with fludioxonil. Seeds were sown in sterilized soil under controlled conditions (12-hour photoperiod, 27°C day/22°C night) and germination percentages were recorded 7 days after sowing. Disease severity was assessed at 7-, 14-, 21-, and 28-days post-germination using a scale from 0 (healthy plant) to 4 (dead or non-germinated plant). Disease incidence was also recorded, considering plants with severity scores ≥2 as infected. Each PPP treatment (clove essential oil, IF23, natamycin) was tested on Carnise and on Oceano cultivar. Potential phytotoxicity effects were assessed visually by including untreated controls and PPP-treated plants without inoculation in triplicate. Disease severity scores were converted into percentages using McKinney's formula. Data were analysed for normality and homogeneity of variance before performing ANOVA. Tukey's HSD test was applied for pairwise comparisons among treatments ($P<0.05$). Results from the efficacy of PPPs as seed treatments against *F. fujikuroi* on susceptible cultivar Carnise showed that the PPPs significantly reduced disease severity compared to the inoculated control from two weeks post-germination (wpg), with the most pronounced effects at 4 wpg. Disease severity percentages were 32.2% (clove oil), 31% (IF23), and 28.7% (natamycin), compared to 28.1% in the chemical control and 71.8% in the inoculated control. Disease incidence followed a similar trend, with PPPs reducing infection rates to 23.3% (IF23), 20% (clove oil), and 18.8% (natamycin), compared to 17% in the chemical control and 86% in the inoculated control. No phytotoxicity was observed in treated plants. Results from the efficacy of PPPs against *F. fujikuroi* on moderately susceptible rice cultivar Oceano showed no significant effects on germination, but germination rates were lower than in Carnise. PPPs effectively reduced disease severity from three wpg, with the greatest differences at four wpg. Disease severity percentages were 29.7% (clove oil), 29.3% (natamycin), and 29% (IF23), compared to 28.2% in the chemical control and 46.5% in the inoculated control. Disease incidence reduction was significant for all treatments except IF23, with values of 18% (clove oil), 15.3% (natamycin), and 14.7% (chemical control), compared to 30.7% in the inoculated control. Overall, natamycin was the most effective PPP, achieving the lowest disease severity and incidence in Carnise and the highest disease incidence reduction in Oceano. Clove oil and IF23 performed similarly, reducing disease severity by an average of 40% in Carnise and 17% in Oceano, and disease incidence by 64% in Carnise and 12% in Oceano. The effect of IF23 on bakanae disease incidence was not statistically significant ($P = 0.069$), however this is mainly due to the moderate resistance of the genotype against the pathogen, which explains the lower disease severity and incidence values obtained in the inoculated control compared to Carnise. The tested PPPs can be considered promising for bakanae disease biocontrol through preventive seed dressing, as they provided a significant reduction of the disease compared to the inoculated control and efficacy like fludioxonil, the standard chemical fungicide approved for

seed dressing of rice. No phytotoxicity of tested PPPs was observed on seedlings of both cultivars.

Citrus

PROJECT: INVESTIGATION OF PREHARVEST CITRUS DISEASES CAUSED BY *COLLETOTRICHUM* SPECIES IN SOUTH AFRICA AND EUROPE: SURVEY, PATHOGENICITY MECHANISMS, FUNGICIDE SENSITIVITY (CITRUS RESEARCH INTERNATIONAL)

Objectives: The objective of this study is to investigate the *Colletotrichum* species associated with citrus in South Africa and Europe through an extensive survey, phylogenetic, pathogenicity, and fungicide sensitivity studies. Field inspections and sampling focus on symptomatic and asymptomatic citrus plants to detect *Colletotrichum* species, with particular attention to orchards in humid areas with summer rainfall across France (Corsica), Greece (Nafplio and Crete), Italy (Calabria and Sicily), Malta, Portugal (Algarve and Azores), and Spain (Andalucía and Valencia). Sampling includes various plant tissues, such as fruit, flowers, twigs, and leaves. Special focus is given to entry hotspots in South and Southwest mainland Portugal, Malta, Crete, Andalucía, and Sicily.

Results 2024: Sampling activities in Greece were conducted in November 2024, covering both the island of Crete (Chania, Mousoures, and Mylopotamos regions), and mainland Greece, (Arta and Agio areas). The survey focused on various citrus species, such as sweet orange (*Citrus* × *sinensis*), mandarin (*Citrus reticulata*), lemon (*Citrus* × *limon*), and lime (*Citrus aurantiifolia*), with samples collected from fruits, leaves, and twigs. Symptoms of anthracnose varied considerably among citrus species. On leaves, irregular necrotic spots with pale brown to purple margins containing acervuli were observed. Fruits exhibited water-soaked, sunken, circular lesions or superficial reddish-brown streaks and bands. Twig and shoot dieback were also common, with affected twigs appearing wilted and showing dark necrotic lesions and cankers, sometimes accompanied by gummosis. In severe cases, branch dieback and the death of young plants were recorded.

Forest trees

PROJECT: LINEE GUIDA OPERATIVE E STRATEGICHE PER LA CONSERVAZIONE DEL FRASSINO IN PIEMONTE (LOSFRAP)

Objectives: The goal of the project LOSFRAP is to build an integrated and multidisciplinary strategy to manage ash trees (*Fraxinus excelsior* L.) in key forest ecosystems of Piemonte threatened by *Hymenoscyphus fraxineus* (T. Kowalski) Baral, Queloz & Hosoya, the causal agent of the ash dieback, a lethal infectious disease affecting *F. excelsior* in Europe.

Collaborations: Istituto per le Piante da Legno e l'Ambiente (I.P.L.A. S.p.A.) Phytosanitary Service of Piedmont Region, different EGAPs (Enti Gestori delle Aree Protette).

Results 2024: In 2024 the systematic phytosanitary monitoring of ash dieback started in 2022 was completed. In 2024, 10 additional forest and urban sites were surveyed, assessing the incidence and severity of the dieback symptoms at the tree level, with a sampling size including 20 ashes per site. Dendrometric, sylvicultural, environmental and meteorological variables were acquired for each tree and site, by following a standardized protocol. Plant tissues were sampled, and diagnostics assays were conducted to assess the presence and the incidence of *H. fraxineus*. The diagnosis of *H. fraxineus* was conducted by means of a taxon-specific assay based on qPCR. Additional macro- and micromorphological observations were conducted on *H. fraxineus* apothecia present on foliar petioles and rachises collected from the

litter under the crown of each monitored ash tree. Microbial isolation trials were conducted, attempting to obtain colonies of *H. fraxineus* and other fungi potentially associated with ash dieback. Artificial inoculation assays were conducted on seedlings of *F. excelsior* to compare the pathogenicity and virulence of different strains, including *H. fraxineus*. The overall structure of the dataset including variables gathered from 2023 and 2024 activities was set up, and algorithms to model the disease as a function of the variables previously mentioned were drafted and tested on a subset of data. Preliminary results indicate that *H. fraxineus* is present and widespread across Piemonte forest ecosystems harboring *F. excelsior*. Of the 200 trees sampled in 2024, 138 were infected by *H. fraxineus*, with an incidence of 28% (considering crown wilting) and -1.4 m of crown loss from the top of the tree. Models from previous data analyses indicate a key role played by ash abundance, density and biomass, as suggested by the positive and significant correlation (P<0.05) between the probability of infection and the tree basal area. Other relevant epidemiological data were obtained and will be further processed and analyzed in 2025.

Conference paper: Lione G. et al. (2024). Environmental and anthropic-driven factors associated with ash dieback caused by *Hymenoscyphus fraxineus* in Northwestern Italy. Book of abstracts – XXIX Congress of the Italian Phytopathological Society – "New challenges in Plant Pathology between sustainable crop production and climate change – 9-11/09/2024, Trento, Italy.

b) Prevention and control

Management of citrus diseases

PROJECT: ETIOLOGY AND CONTROL OF COLLETOTRICHUM DISEASES ON CITRUS IN FLORIDA (KEYPLEX)

Objectives: The study aims to: i) isolate *Colletotrichum* strains from citrus samples collected in Florida and characterize them through morphological traits and DNA sequence analysis; ii) to evaluate the pathogenicity of selected *Colletotrichum* species on citrus fruits and twigs under controlled conditions; iii) to assess the baseline sensitivity of *Colletotrichum* isolates to chemical fungicides and alternative compounds, such as KeyPlex products, in laboratory conditions. The effectiveness of various fungicides, biopesticides, botanical, and nutritional products will be tested in detached fruit trials and field experiments. Based on the results, strategies will be developed to improve citrus plant health. Finally, the results will be disseminated through scientific publications, extension articles, congress presentations, and video conferences to benefit Florida citrus growers and extension services.

Results 2024: The study focused on *Colletotrichum gloeosporioides*, a major fungal pathogen affecting *Citrus sinensis* in Florida, aiming to identify and characterize the species, assess its pathogenicity, and evaluate its sensitivity to fungicides and biocontrol products. A total of 200 fungal isolates were obtained from symptomatic citrus orchards, of which 130 were identified as *Colletotrichum-like* based on morphological characteristics. Molecular analyses of five genetic loci (gapdh, act, tub2, gs, ApMat) confirmed that all isolates belonged to *C. gloeosporioides*. Pathogenicity tests conducted on *C. sinensis* cv. Valencia and Tarocco demonstrated that all tested isolates caused stem-end rot, with significant differences in aggressiveness among them. Statistical analyses (ANOVA and Tukey's HSD test) confirmed the pathogenic potential of the species, identifying the CVG1959 strain as the most aggressive.
Sensitivity tests were performed on 100 isolates using three synthetic fungicides: pyraclostrobin (QoI), fluopyram (SDHI), and fenbuconazole (DMI). Among these,

pyraclostrobin was the most effective, followed by fluopyram, while fenbuconazole showed the lowest efficacy. However, a significant number of isolates exhibited resistance to these fungicides, likely due to prolonged and excessive use in citrus production. Additionally, 10 isolates were tested against three organic products from Keyplex (AWP, SPORAN, and KP120). None of these products showed any inhibitory effect on *C. gloeosporioides*, indicating that they are not effective in controlling the pathogen. Overall, this study confirmed *C. gloeosporioides* as a major threat to citrus production in Florida. The high degree of fungicide resistance observed raises concerns about the long-term efficacy of chemical control strategies, while the ineffectiveness of the tested KeyPlex products highlights the need for alternative management approaches. Future research should focus on further pathogenicity tests *in planta* and explore additional control strategies to mitigate the impact of *C. gloeosporioides* on citrus production.

Publications on ISI journal: Annex V, publication no. 26.

Management of turfgrass diseases

PROJECT: THE ROYAL AND ANCIENT CHAMPIONSHIP - EFFECTS OF BIOSTIMULANTS AND MICROORGANISMS AGAINST MOST COMMON TURFGRASS DISEASES IN ITALY

Objectives: The purpose of the project is to evaluate the effectiveness of biostimulants, alone or in combinations with microorganisms that could be antagonists of the most common turfgrass diseases in Italy, in particular *Clarireedia* spp. (Dollar spot) and *Rhizoctonia solani* (brown patch) and recently introduced warm season grasses diseases (*Bipolaris* spp.). The study is also focused on evaluating the effects of these products on stress resistance.

Results 2024: Greenhouse trials were carried out with biocontrol agents, alone and in combination with different biostimulants, with or without artificial pathogen inoculation, on different turfgrass species. Most effective combinations were applied under field conditions. A low efficacy of tested products was observed against the pathogens under study.

Monitoring and predicting

PROJECT: PROGETTO PSR REGIONE PIEMONTE – SERVIZIO DI MONITORAGGIO AVANZATO PER L'IRRIGAZIONE E FERTILIZZAZIONE SOSTENIBILE E DIFESA INTEGRATA PER LE ORTICOLE DI PIENO CAMPO (MONITORA).

Objectives: Aim of the project was to provide an integrated decision support system for the management of irrigation, fertilization and crop protection based on advanced and shared monitoring at a territorial level, accessible and usable by the entire supply chain in an easy and economical way.

Collaborations: SATA S.r.L., Servizi Integrati di consulenza e controlli per la filiera agroalimentare, Quargnento, (AL)

Results 2024: The project ended in April 2024, consequently activities carried out during 2024 were mainly related to the preparation of deliverables and reports, as well as the dissemination of technologies developed, and results achieved during the project.

Other publications: Annex V, publications no. 40, 42, 43, 45, 47.

Precision agriculture

PROJECT: PROGETTO PSR REGIONE PIEMONTE – VI.P. VITICOLTURA DI PRECISIONE

Objectives: To identify and introduce an optimal vineyard management model based on the use of innovative precision viticulture tools that allow to detect the health state of the crop in a timely manner and to apply a control strategy in a targeted manner based on the actual conditions.

Results 2024: Within the VI.P project, a vineyard located in Castiglione Tinella (Cuneo Province) was weekly monitored by visual scouting for the development of downy and powdery mildew infections. An experimental protocol was applied in the vineyard, comparing the standard farmer disease management practice to an experimental integrated disease management strategy supported by disease prediction models, an organic farming strategy supported using disease prediction models, a precision crop protection strategy supported by an electric precision sprayer developed by project partners. The IPM and organic strategies were able to control the diseases like in farmer practice. The vineyard was also scouted with drones equipped with multispectral cameras to investigate and correlate the plant disease development with the collected images. The elaboration of images collected was able to identify diseased and healthy plants. Some limitations of this detection system were identified.

PROJECT: IMAGING DIAGNOSIS OF VINE DISEASES USING NEURAL NETWORKS AND DEEP LEARNING (DIVINE).

Objectives: Aim of the project is to develop a smart non-destructive system able to recognize plant diseases on grape.

Results 2024: A set of data and images of leaves of different varieties of diseased and healthy vine, were collected in controlled conditions and in vineyards to be used to train a model capable of automatically recognizing plant diseases (or their absence).

Management of vegetable diseases

PROJECT: MANAGEMENT MODELS TO PROMOTE SUSTAINABILITY AND RESILIENCE OF AGRICULTURAL PRODUCTION SYSTEMS

Objectives: The project aims to develop, evaluate and implement smart, multifunctional and circular solutions for reducing external inputs and improving productivity, health, quality, safety and security of crops.

Results 2024: experimental trials were carried out in greenhouse, open field and phytotrons on vegetable crops investigating the role of biotic and abiotic stresses and the efficacy of biofertilizers on plant disease suppression. Some of the biofertilizers tested, including compost and insect frass, showed to reduce Fusarium wilts on tomato and lettuce. Field experiments were carried out on wheat and grapes to evaluate the efficacy of biocontrol agents and biostimulants on plant diseases. Furthermore, trials were carried out to investigate the efficacy of novel probes provided by Polito in describing plant health status.

Publications on ISI journal: Annex V, publications no. 9, 10, 28.

Other publications: Annex V, publications no. 57

PROJECT: PERCIVAL - PROCESSI DI ESTRAZIONE DI BIOPRODOTTI DA SCARTI AGROINDUSTRIALI E VALORIZZAZIONE IN CASCATA

Objectives: The purpose of the project is to evaluate the effectiveness of biofertilizers, biostimulants and biocontrol agents on the reduction of plant diseases on vegetable crops.

Results 2024: Experimental trials were carried out in greenhouse on vegetable crops investigating the efficacy of biofertilizers, biocontrol agents and biostimulants on foliar and

soil-borne pathogens. Preliminary results showed the capacity of extracts from agrifood wastes to partially control powdery mildew of tomato.

PROJECT: EFFECT OF INNOVATIVE SOIL GEO-INFESTATION TECHNIQUES FOR THE CONTAINMENT OF TELLURIC PATHOGENS (OP SOLE E RUGIADA SACPA)

Objectives: Various measures are used to control pests and pathogens; however, modern agriculture has made extensive use of chemical control strategies. Research continues to develop new techniques and approaches to reduce the impact of soilborne pathogens on agricultural crops. Soil disinfestation with microwaves offers promising prospects in the field of crop protection. Novel applicator structures have been developed to restrict the application of microwave energy to the surface layers of the soil. The effectiveness of the treatment was assessed post-treatment by means of laboratory analyses to determine the survival of propagules and resistance structures of selected soilborne pathogens artificially introduced into the soil.

Results 2024: The microwave treatment was carried out on a commercial farm. The exposure of the propagules of *Rhizoctonia solani* at a depth of 6 cm for 40 min. of microwaves treatment significantly reduced pathogen viability with an efficacy of 99 %. Exposure to the treatments for 20 min and 30 min significantly reduced the survival of the pathogen propagules compared to the untreated control with a significantly similar result of 47 % - 58 % respectively. Exposure of the bioassays based *Fusarium oxysporum* f.sp. *lactucae* placed at a depth of 6 cm for 40 min of treatment significantly reduced the viability of the chlamydospore of 62% compared to the control while treatments duration of 20 min and 30 min resulted partially effective (21% and 39% reduction). The prototype machine requires further fine-tuning to improve treatment uniformity. The obtained results showed positive effects in reducing the survival of propagules and resistance structures of pathogens responsible for severe losses in field, depending on the duration of the treatment and the depth of the treated soil. Preliminary analysis demonstrated that microwave soil heating had an immediate impact on soil microbial communities. Soil treatment with microwave requires further verification.

c) *Molecular diagnostics; diagnostic test validation; detection of seedborne pathogens; detection of fruit and berry fruit leaf, wood, and root pathogens.*

PROJECT: AGROINNOVA DIAGNOSTICS

Objectives: The diagnostic laboratory of Agroinnova aims at: i) providing phytosanitary service to private stakeholders; ii) providing support to the regional and national phytosanitary offices; iii) develop diagnostic tools to detect known, emerging and new pathogens of fruit, horticulture, ornamentals and cereal crops.

Collaborations: several seed companies, farmers' organizations, Piedmont Region Phytosanitary Services

Results 2024: during 2024 the laboratory obtained the status of Official Phytosanitary Laboratory from the Piedmont Region. This recognition includes the laboratory in the network of the national phytosanitary laboratories authorized to carry out official phytosanitary analysis to detect and identify fungi, bacteria and oomycets. To maintain this status the laboratory must retain the accreditation with the norm UNI CEI ISO/IEC 17025 General:2018 *Requirements for the competence of testing and calibration laboratories* and the accreditation with the national regulations: Dlgs. n. 19, 2 February 2021, art. 14 and DM

12 april 2022, n. 169819, art. 11. The laboratory participated to the mandatory proficiency test on the detection of the pathogen *Phyllosticta citricarpa* , causal agent of black spot of citrus, listed by the European Plant Protection Organization (EPPO) as A1 quarantine pathogen. The laboratory participated in one interlaboratory test with the Regional Phytosanitary Office on *Erwinia amylovora*, the fire blight bacterial agent of apple. On both these evaluation processes the laboratory reached conformity results. For the first time the laboratory participated to a proficiency test in the area of entomology for the identification of *Bactrocera dorsalis*, the oriental fruit fly, and *Bactrocera zonata*, the peach and guava fruit fly, in view of a future extension of the official accreditation.

In 2024 two diagnostic tools were developed for the detection of one emerging pathogen *Trichoderma afroharzianum* the causal agent of Trichoderma ear rot, and two common and widespread *Rhizoctonia solani* and *Colletotrichum coccodes* on potato.
T. afroharzianum was recently reported as a maize pathogen in Germany, France and in Italy. Studies carried our previously showed that *T. afroharzianum* can be seedborne. Thirteen seedborne isolates were used to design species-specific primers on the translation elongation factor 1α as gene, and to develop a SYBR Green quantitative PCR to detect and quantify *T. afroharzianum* in maize seeds. The detection was developed following the standardized guidelines EPPO standard PM 7/98 Analytical sensitivity tested using serial dilutions of *T. afroharzianum* DNA revealed a detection limit of 50 fg, even in the presence of maize seed DNA. The assay enables specific and sensitive detection of target DNA in asymptomatic samples, providing a valuable tool for early target detection and quantification during seed certification, a potential source of inoculum.
Colletotrichum coccodes, agent of black dot, and *Rhizoctonia solani* anastomosis group 3 (AG-3), agent of black scurf and stem canker, are two economically important pathogens of potato crops. Worldwide distributed, both affect solanaceous species, such as potatoes, widely grown in Northern Italy. A duplex TaqMan quantitative real-time PCR was developed for the identification of these species in propagation material, based on two singleplex methods previously validated. The validation was performed according to EPPO PM 7/98 standard guidelines. The limit of detection (LOD) of the method, assessed using serial dilution of targets DNA, was 10 fg. The assay was able to detect and distinguish, with a single run, between these two fungal species, allowing their early detection in potato tubers.

d) Plant and food biosecurity, food safety and circular agriculture in the frame of circular health.

Circular Health

PROJECT: PROGETTO COMPAGNIA SAN PAOLO IA - CIRCULAR HEALTH. SALUTE CIRCOLARE PER IL SETTORE AGROALIMENTARE.

Objectives: Promoting innovative research bringing scientific progress in the artificial intelligence field and with concrete economic and social implications in the territory for the agro-food sector.

Results 2024: During 2024 activities were mainly related to the preparation of deliverables and reports, as well as the validation of technologies, done by the partner CNR-IRCrES.

Publications on ISI journal: Annex V, publications no. 14

Other publications: Annex V, publication no. 53.

PROJECT: CHEDIH. CIRCULAR HEALTH EUROPEAN DIGITAL INNOVATION HUB.

Objectives: Circular Health European Digital Innovation Hub (CHEDIH) is an Italian EDIH dedicated to the food and health industries. It is a one-shop shop to support the digitalisation of SMEs and public administrations concerned with food and health. It is active in Piedmont, the Aosta Valley and beyond. CHEDIH walks clients through all stages of their digital transition. Following a digital maturity level assessment, a customised roadmap is built, and the client is put in contact with technology providers to test technologies, gain access to technical expertise and initiate feasibility studies. Training is provided to implement the technology. Clients are supported in their search for public and private funds and revision of their business plan.

Results 2024: Agroinnova's role was to define the catalogue of services to provide to agrifood company and contacts with companies started to provide services during 2025.

PROJECT: WALNUT. CLOSING WASTEWATER CYCLES FOR NUTRIENT RECOVERY.

Objectives: WalNUT aims to close the wastewater cycles for nutrient recovery. Wastewater streams are considered a promising resource to mitigate the soil nutrient imbalance and to recover nutrients for plant fertilizing purposes. Nutrients from this large-scale recovery process can be used for bio-based fertilizers offering a new, circular and sustainable model to tackle the limited nutrient-mineral reserves and it is a crucial environmental issue. These bio-based fertilizers will ensure food safety, minimize wastewater carbon footprint and protect nutrients natural reserves.

Results 2024: Agroinnova carried out different activities to compile knowledge of recovered bio-based fertilizer technologies and products for improving soil and plant health. Agroinnova carried out greenhouse and field trials in 2024 applying the fertilizers developed by project partners, such as biosphosphate and algae-based fertilizers, and investigating their capacity to suppress soil-borne diseases on vegetable crops.

PROJECT: FOOD SAFETY: STUDY, IMPROVEMENT AND APPLICATION OF PURIFIED WATER REUSE SYSTEMS IN AGRICULTURE, FOR ANIMAL FARMING AND IN THE HORTICULTURAL SECTOR (RENEWATER).

Objectives: "ReneWater" project aims to evaluate the microbiological safety of short-cycle leafy vegetables irrigated with reclaimed wastewater greenhouses simulations assessing the microbiological safety in short-cycle leafy vegetables. The aim of the project is the acquisition of data relating to the safety of reclaimed water and primary production to evaluate the presence of pathogens, antimicrobial resistance factors and chemical contaminants. The project addressed the consumer resistance and food safety concerns to purchasing products irrigated with reclaimed water.

Results 2024: The study involved experimental trials in greenhouses, using basil (*Ocimum basilicum*), lettuce (*Lactuca sativa*), and rocket (*Eruca vesicaria*) cultivated in a simulated soilless floating system. The nutrient solution in the tanks containing the crops' roots was spiked with non-pathogenic Escherichia coli, miming an indicator microorganism for hygiene, at a concentration of 1×10^6 CFU/mL. The crops were analyzed 24 hours after the inoculation of *E. coli* (ATCC avirulent strain) and subsequently after 40 and 70 days of vegetation growth, corresponding to the period until plants reached commercial maturity. For both lettuce and rocket, the concentrations of *E. coli* in the nutrient solution, peat and seedlings were found to be below the detection limit of 40 days post-inoculation (< 10 CFU/g). For basil, this result was achieved after 70 days. The findings suggest that crops cultivated in soilless systems irrigated with reclaimed wastewater are microbiologically safe at the end of the growth cycle. With

proper treatment, reclaimed water can be used in agriculture without compromising food safety, providing a sustainable solution to recover resources that would otherwise be lost and to reduce the environmental impact of agriculture.

Conference paper: Provera A. et al. (2024) Reclaimed wastewater in agriculture: greenhouses simulations assessing the microbiological safety in short-cycle leafy vegetables. 2nd World Congress of the Global Harmonization Initiative - "Connecting Food Security, Safety, Health and Sustainability – Challenges Ahead", 25-27 June, Rotterdam, The Netherlands.

Soil biodiversity

PROJECT: - EXCALIBUR. EXPLOITING THE MULTIFUNCTIONAL POTENTIAL OF BELOWGROUND BIODIVERSITY IN HORTICULTURAL FARMING.

Objectives: Excalibur plans to enhance the knowledge on soil biodiversity dynamics and its synergistic effects with prebiotic and probiotic approaches in horticulture, using a multi-actor approach. To pursue this aim, new multifunctional soil microbial inoculants (bio-inocula) and bio-effectors will be tested on three model crops of economic importance (tomato, apple, strawberry) under different experimental and open-field conditions across Europe, and the feed-feedback effect of/on native biodiversity monitored. To go beyond the multitude of studies on the links between soil biodiversity and plant health, Excalibur will develop a comprehensive strategy of soil management improving the effectiveness of biocontrol and bio fertilization practices in agriculture.

Results 2024: new multifunctional soil microbial inoculants (bio-inocula) and bio-effectors were planned for 2 model crops of economic importance (tomato and strawberry), with attention on the links between soil biodiversity and plant health. A set of microbial antagonists (*Fusarium, Trichoderma,* and *Bacillus*) and biostimulants were evaluated during 2024 in greenhouse conditions on potted plants against soil-borne diseases of tomato and strawberry. *Fusarium oxysporum* MSA35, mycorrhiza consortia and an experimental biostimulant were among the most effective to reduce Fusarium wilt on tomato and Rhizoctonia crown and root rot on strawberry. The most effective products were applied in field trials on tomato and strawberry carried out in farms located in Moretta and Boves (Cuneo province), confirming a reduction of soil-borne diseases. Rhizosphere soil samples were collected from the plants during field trials and DNA was extracted in order to evaluate by qPCR and NGS during next year the impact of applied products on bacterial and fungal communities.

Publications on ISI journal: Annex V, publications no. 4, 18.

e) Postharvest diseases

Hazelnut nut defects

PROJECT: "NOCCIOLA DI QUALITÀ" PROJECT FUNDED BY PIEDMONT REGION

Objectives: Hazelnut defect is a generic definition of a condition affecting the nuts after harvest and that reduces considerably the nutritional and economic value of the crop. Several abiotic and biotic factors concur do the development of the defects. The project aims at: i) proposing different control strategies against *Halyomorpha halys*, the stinky bug; ii) characterizing the predisposing factors for the defect of fruits due to the deterioration in pre- and post-harvest; iii) monitoring of biotic and abiotic factors and their correlations that favor the contamination by mycotoxins; iv) the dynamics of the pre-harvest fall, a multifactorial

physiological criticality with an important impact on productivity. Agroinnova is involved in objectives ii and iii.

Collaborations: Fondazione AGRION

Results 2024: in 2024 Agroinnova concluded the activities related to the characterization and identification of the causal agents, isolated in previous years in several orchards. The identification carried out with morphological and molecular methods showed that the most common fungal pathogens belong to the genus: *Alternaria* sp., *Diaporthe* sp., *Fusarium* spp., *Passalora* (*Trichothecium* sp.) and *Aspergillus* sp.. The recording of climatic conditions in the orchards and the capture of the aerial fungal inoculum during the cropping season and analysed with a metabarcoding tool confirmed the presence of the genus *Alternaria* and *Fusarium* mainly toward the end of the cropping cycle. These fungi showed the optimum growing rate at 27 ±1.5 °C and 21±2°C respectively.

Publications on ISI journal: Annex V, publications no. 33.

f) COMMUNICATION & DISSEMINATION

Agroinnova scientists participated in several national and international congresses listed in Annex VI with invited presentations, oral and poster presentations. Agroinnova also engaged in outreach activities, listed in Annex VII, mainly in Piedmont Region but also in foreign countries.

Agroinnova scientists, besides producing high quality research papers published on ISI journals (Annex V). publish actively on national journals to communicate the results of the research carried out with the largest possible audience and it continues to publish the Journal on crop protection “Protezione delle colture”.

CONCLUDING REMARKS

In 2024, the allocation of space (greenhouses, laboratories, warehouse, offices and experimental vineyard) from DISAFA to Agroinnova was reviewed and defined by a resolution of the Department Council, which was implemented by the Management Committee of the Interdepartmental Center.
Maintenance work on phytotrons, upgrading and retrofitting of electrical systems in the areas of above ground crops, heating in greenhouses were completed and the purchase of two new phytotrons was arranged. Three new heat pumps needed for the nursery sector were installed. Completed the cleaning and tidying up of the spaces outside the greenhouses, shade house and warehouse and inside all greenhouses and in individual sectors. These actions were necessary to have available and fully functional all the spaces needed to organize the research activities planned for 2025 (see document research activities 2025).

Based on what this document outlines we can conclude that the research activities carried out by Agroinnova scientists and collaborators during 2024 are satisfactory. These have resulted in and brought to a considerable amount of scientific information that was well communicated to, and transferred to, stakeholders. We trust that the number of projects, the range of activities and their impact will grow in 2025 (see planning document) by both creating partnerships with and integrating the knowledge of scientists that have backgrounds from different scientific areas, affiliated to several departments of the University of Torino.

ANNEXES

ANNEX I - The management committee

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ANNEX III – The team

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Alberto Alma	DISAFA - Entomology Unit	Full Professor, Director
Monica Mezzalama	DISAFA – Plant Pathology Unit	Associate Professor, Deputy Director
Paolo Gonthier	DISAFA - Plant Pathology Unit	Full Professor, collaborator
Davide Spadaro	DISAFA - Plant Pathology Unit	Full Professor, collaborator
Paolo Sabbatini	DISAFA – Viticulture	Full Professor, collaborator
Chiara Ferracini	DISAFA - Entomology Unit	Assistant professor, collaborator
Elena Gonella	DISAFA - Entomology Unit	Assistant professor, collaborator
Vladimiro Guarnaccia	DISAFA Plant Pathology Unit	Associate Professor, collaborator
Massimo Pugliese	DISAFA Plant Pathology Unit	Associate Professor, collaborator
Guglielmo Lione	DISAFA Plant Pathology Unit	Assistant professor, collaborator
Stefania Savoi	DISAFA – Viticulture	Assistant professor, collaborator
Gilardi Giovanna	AGROINNOVA	Graduated technician, PhD
Bertetti Domenico	AGROINNOVA	Graduated technician
Zerbini Gabriele	AGROINNOVA	Technician
Valerio Antonella	DISAFA - Administration	Chief secretary
Guido Boella	Department of Computer Science	Full Professor, collaborator
Cristina Varese	DBIOS	Full Professor, collaborator
Francesca Barbero	DBIOS	Assistant professor, collaborator
Mery Malandrino	Department of Chemistry	Associate Professor, collaborator

ADDITIONAL STAFF SUPPORTED THROUGH PROJECTS

SURNAME AND NAME	ROLE
Vasileiadou Athina	Graduated technician
Valfrè Paolo	PhD student
Carlo Roperto	PhD student
Luca Alfarano	PhD student
Martina Morlino	Fellow
Irene Germanetto	Fellow
Manfrin Samuel	Field technician

ANNEX IV - List of projects 2024

FUNDING BODY	TITLE and Responsible	DURATION AND ROLE
European Union – H2020	Exploiting the multifunctional potential of belowground biodiversity in horticultural farming (EXCALIBUR) – Massimo Pugliese	2019-2024 PARTNER
	WalNUT – Closing Waste water cycles for nutrient recovery – Massimo Pugliese	2022-2025 PARTNER
European Union – Digital Europe Programme	CHEDIH - Circular Health European Digital Innovation Hub – Massimo Pugliese	2023-2025 PARTNER
Italian Ministry of Health	"ReNEWater": Food safety: study, improvement and application of systems for the reuse of purified water in agriculture, for zootechnical purposes and in the horticultural supply chain" – Massimo Pugliese	2022-2024 PARTNER
PSR- Rural Development Program -Piedmont Regional Government	VI.P. - Viticoltura di Precisione (Precision viticulture) – Massimo Pugliese	2020-2023 PARTNER
	MONITORA - Advanced monitoring service for irrigation and sustainable fertilization, and integrated control for open field vegetables - Massimo Pugliese	2020-2023 PARTNER
AGER – Agroalimentare e ricerca	From SOil to Soil: origin and remediation to KIWIfruit Vine Decline Syndrome (SOS-KIWI)- Davide Spadaro	2023-2027 PARTNER
Piedmont Regional Government	"Nocciola di Qualità" – Hazelnut quality. Targeting the problems affecting the industrial quality of hazelnut. – Monica Mezzalama	2021-2024 PARTNER
Piedmont Regional Government	KIPOTRÁ – La moria del kiwi- Valutazione sull'impiego di innovative portainnesti come mezzo agronomico per prevenire lo sviluppo dei sintomi - Davide Spadaro	2024 PARTNER
Compagnia di San Paolo	CH4I - Circular Health for Industry Development of a traceability system for agrifood products using blockchain technology. Development of AI models to monitor the risk of plant disease outbreaks. – Massimo Pugliese	2020-2023 PARTNER

FUNDING BODY	TITLE and Responsible	DURATION AND ROLE
Compagnia di San Paolo	BIO-SAL "Biodiversità e salute delle piante" (Biodiversity and Plant Health) – Massimo Pugliese	2023-2025 PARTNER
KeyPlex (private company)	Etiology and control of Colletotrichum diseases on citrus in Florida – Vladimiro Guarnaccia	2022-2024 COORDINATOR
Citrus Research International	Investigation of preharvest citrus diseases caused by *Colletotrichum* species in South Africa and Europe: survey, pathogenicity mechanisms, fungicide sensitivity – Vladimiro Guarnaccia	2024-2026 COORDINATOR
R& A (The Royal and Ancient Golf Club of St Andrews)	"Effects of biostimulants and microorganisms against the most common turfgrass diseases in Italy" – Massimo Pugliese	2023-2025 PARTNER
Italian Ministry for Research	Management models to promote sustainability and resilience of agricultural production systems. PNRR AgriTech Spoke 6 – Massimo Pugliese	2023-2025 PARTNER
BIOLCHIM S.p.A.	Efficacy of prebiotics and probiotics in the control of kiwifruit vine decline – Davide Spadaro	2022-2024 COORDINATOR
CEAP – Bacardi	Phytosanitary status of officinal species in Piedmont: identification of the causal agents and assessment of seed and of propagation material health – Davide Spadaro	2023-2024 COORDINATOR
SA.PI.SE. - SARDO PIEMONTESE SEMENTI SOC. COOP.	Susceptibility of rice to *Fusarium fujikuroi* and *Pyricularia oryzae* – Davide Spadaro	2022-2024 COORDINATOR
SA.PI.SE. - SARDO PIEMONTESE SEMENTI SOC. COOP.	Integrated approach to the management of bakanae and blast diseases in rice – Davide Spadaro	2023-2024 COORDINATOR
XEDA International SAS	Evaluation of the efficacy of plant protection products for the control of *Fusarium fujikuroi* on rice seeds – Davide Spadaro	2024 COORDINATOR
Regione Piemonte - Settore Servizi di sviluppo e controlli per l'agricoltura	Kiwifruit Vine Decline Syndrome – Evaluation of the use of innovative rootstocks as an agronomic strategy to prevent symptom development (KIPOTRÁ) – Davide Spadaro	2024 PARTNER

FUNDING BODY	TITLE and Responsible	DURATION AND ROLE
RVF Società Agricola Sperimentale	Evaluation of the effectiveness of essential oil-based formulations for the control of major grapevine pathogens – Davide Spadaro	2024-2025 COORDINATOR
Compagnia di San Paolo	TRANSITION - inTegRated And iNnovative StrategIes for susTainable frult production - Davide Spadaro	2024-2026 COORDINATOR
AOP PIEMONTE SOC. CONS. A R.L	Solutions for preventing and mitigating Kiwifruit Vine Decline Syndrome – Davide Spadaro	22024-2026 PARTNER
AOP PIEMONTE SOC. CONS. A R.L	White haze and dry lenticel rot of apples: study of the possible control strategies	2024-2026 COORDINATOR

ANNEX V– List of publications 2024[1]

ISI JOURNALS

1. Aloi F., Luque-Cruz C., Agustí-Brisach C., Spadaro D., Guarnaccia V. (2024) First report of almond decline syndrome caused by *Neofusicoccum parvum* in Italy. Plant Disease, 108 (11), 3415. https://doi.org/10.1094/PDIS-07-24-1538-PDN
2. Bhunjun, C. S., Chen, Y. J., Phukhamsakda, C., Boekhout, T., Groenewald, J. Z., McKenzie, E. H. C., Guarnaccia V., ... & Crous, P. W. (2024). What are the 100 most cited fungal genera? Studies in Mycology, 108(1), 1-412. https://doi.org/10.3114/sim.2024.108.01
3. Bosco S., Prencipe S., Mezzalama M., Spadaro D. (2024) Screening and characterization of bacterial and fungal endophytes as potential biocontrol agents for rice seed dressing against *Fusarium fujikuroi*. Biological Control 196, 105580. https://doi.org/10.1016/j.biocontrol.2024.105580
4. Canfora L., Pugliese M., Furmanczyk E. M., (2024). Editorial: The impact of environmentally friendly agricultural practices on soil microbiome. Front. Microbiol. 15:1505220. doi: 10.3389/fmicb.2024.1505220
5. Garello M., Piombo E., Buonsenso F., Prencipe S., Valente S., Meloni G.R., Marcet-Houben M., Gabaldón T., Spadaro D. (2024) Several secondary metabolite gene clusters in the genomes of ten *Penicillium* spp. raise the risk of multiple mycotoxin occurrence in chestnuts. Food Microbiology, 104532. https://doi.org/10.1016/j.fm.2024.104532
6. Garibaldi A., Bertetti D., Martino I., Gullino M. L. (2024) First Report of Botrytis Blight caused by *Botrytis cinerea* on *Plectranthus scutellarioides* in Italy. Plant Disease, 108 (3), 805. - https://doi.org/10.1094/PDIS-09-23-1932-PDN.
7. Garibaldi A., Bertetti D., Martino I., Luongo I., Gullino M.L. (2024) First report of *Heterophoma verbasci-densiflori* on *Verbascum chaixii "Album"* in Italy. Journal of Plant Pathology, 106 (1), 289. - https://link.springer.com/article/10.1007/s42161-023-01539-2.
8. Garibaldi A., Luongo I., Bertetti D., Martino I., Valfrè P., Gullino M.L. (2024) First report of *Botrytis cinerea* on leaves of some old rhododendron *(Rhododendron arboreum)* plants grown in Northern Italy. In Journal of Plant Pathology, 106 (3), 1405. - https://link.springer.com/article/10.1007/s42161-024-01647-7.
9. Gilardi G., Pugliese M., Garibaldi A., Gullino M.L. (2024) Emerging vegetable crop diseases and their management options (2024). CABI Reviews (2024) 19:1.
10. Gilardi G., Tabone G., Gullino M.L., Garibaldi A. (2024) Effect of the use of biocontrol agents and resistance inducers against *race 1 of Fusarium oxysporum f. sp.* lactucae on lettuce in a simulated climate change scenario. Journal of Plant Pathology, 106 (1), 23-30
11. Guarnaccia V., Remolif G.M.E., Nari L., Gualandri V., Angeli D., Oettl S., Dijksterhuis J., Boekhout T., Spadaro D. (2024) Characterization of fungal species involved in white haze disorder on apples in Northern Italy and description of *Golubevia mali* sp. nov. and

[1] Submitted papers and conference papers are not listed

Entyloma mali sp. nov.. Postharvest Biology and Technology, 209, 112678. https://doi.org/10.1016/j.postharvbio.2023.112678

12. Guaschino M., Garello M., Nari L., Zhimo Y.V., Droby S., Spadaro D. (2024) Soil, rhizosphere, and root microbiome in kiwifruit vine decline, emerging multifactorial disease. Frontiers in Microbiology, 15, 1330865. https://doi.org/10.3389/fmicb.2024.1330865
13. Guaschino M., Prencipe S., Somera T., Tabone G., Spadaro D. (2025). Development of a qPCR assay for early detection and quantification of *Phytopythium vexans* in kiwifruit plant and soil affected by Vine Decline Syndrome. Plant Dis. 2025 Jan 14. https://doi.org/10.1094/PDIS-09-24-2044-RE
14. Gullino M.L., Pasquali M., Pugliese M., Capua I. (2024) *Positioning plant health within the evolving human-animal-environmental health paradigms*. One Health, vol. 19. - https://www.sciencedirect.com/science/article/pii/S235277142400257X.
15. Gusella, G., Gugliuzzo, A., Guarnaccia, V., Martino, I., Aiello, D., Costanzo, M. B., ... & Polizzi, G. (2024) Fungal Species Causing Canker and Wilt of *Ficus carica* and Evidence of Their Association by Bark Beetles in Italy. Plant Disease, 108(7), 2136-2147. https://doi.org/10.1094/PDIS-01-24-0251-RE
16. Kong, P., Guarnaccia, V., Carter, C., & Hong, C. X. (2024). First report of *Calonectria henricotiae* causing boxwood blight in Switzerland and Italy. New Disease Reports, 50(2), e70006. https://doi.org/10.1002/ndr2.70006
17. Mancuso T., De Cianni R., Di Vita G.A., Spada E., Brun F., Spadaro D., Zanchini R. (2024) Understanding Consumers' Perceptions of Tomato Agricultural Innovation: Exploring the Nexus between Sustainability, Health and Consumer Beliefs. Journal of Cleaner Production, 435, 140528. https://doi.org/10.1016/j.jclepro.2023.140528
18. Manfredini A., Pugliese M., Valfrè P., Canfora L. (2025). Advancing strain-specific Taqman assays for *Trichoderma asperellum* detection in commercial agricultural settings. Biological Control, 202, 105723.
19. Marcet-Houben M., Gabaldón T., Spadaro D. (2024) Several secondary metabolite gene clusters in the genomes of ten *Penicillium* spp. raise the risk of multiple mycotoxin occurrence in chestnuts. Food Microbiology, 104532. https://doi.org/10.1016/j.fm.2024.104532
20. Martino, I., Agustí-Brisach, C., Nari, L., Gullino, M. L., & Guarnaccia, V. (2024). Characterization and pathogenicity of fungal species associated with dieback of apple trees in Northern Italy. Plant Disease, 108(2), 311-331.
21. Martino, I., Lione, G., Garbelotto, M., Gonthier, P., & Guarnaccia, V. (2024). Modeling the Effect of Temperature on the Severity of Blueberry Stem Blight and Dieback with a Focus on *Neofusicoccum parvum* and Cultivar Susceptibility. Horticulturae, 10(4), 363. https://doi.org/10.3390/horticulturae10040363
22. Martino, I., Monchiero, M., Gullino, M. L., & Guarnaccia, V. (2024). Characterization and pathogenicity of fungal species associated with hazelnut trunk diseases in North-western Italy. Journal of Plant Pathology, 1-19. https://doi.org/10.1007/s42161-024-01595-2

23. Martino, I., Spadaro, D., & Guarnaccia, V. (2024). Fungal trunk pathogens of fruit and nut tree crops: identification, characterization, detection and perspectives for a critical global issue. Plant Disease, in print. https://doi.org/10.1094/PDIS-10-24-2069-FE

24. Martino, I., Sorrentino, R., Piccirillo, G., Battaglia, V., Polizzi, G., Guarnaccia, V., Lahoz, E. (2024). *Colletotrichum fioriniae*, causal agent of postharvest avocado fruit rot in Southern Italy. Phytopathologia Mediterranea, 375-383.

25. Mosca S., Aci M.M., Procopio G., Vadalà V., Vizzari G., Francomano E., Mohamed N.Z., Li Destri Nicosia M.G., Agosteo G.E., Spadaro D., Schena L., Malacrinò A. (2024) Integrated analyses of the plant and soil microbiome identify *Phytopythium vexans* as agent of the Kiwifruit Vine Decline Syndrome. Plant and Soil, in print. https://doi.org/10.1007/s11104-024-06891-5

26. Piattino V., Aiello D., Dardani G., Martino I., Flores M., Aćimović S.G., Spadaro D., Polizzi G., Guarnaccia V. (2024) *Lasiodiplodia iraniensis* and *Diaporthe* spp. are associated with twig dieback and fruit stem-end rot of sweet orange, Citrus sinensis, in Florida. Horticulturae, 10(4), 406. https://doi.org/10.3390/horticulturae10040406

27. Primisser S., Deltedesco E., Spadaro D., Oettl S. (2024) *Ramularia mali* associated with symptoms of dry lenticel rot, an emerging postharvest disease on apples in Italy. Plant Disease, 108 (8), 2579. https://doi.org/10.1094/PDIS-04-24-0826-PDN

28. Pugliese M., Gilardi G., Garibaldi A., Gullino M.L. (2024) The Impact of Climate Change on Vegetable Crop Diseases and Their Management: The Value of Phytotron Studies for the Agricultural Industry and Associated Stakeholders. Phytopathology, 114 (5), 843-854. - https://apsjournals.apsnet.org/doi/10.1094/PHYTO-08-23-0284-KC.

29. Remolif G., Buonsenso F., Schiavon G., Garello M., Spadaro D. (2024) Efficacy of Essential Oil Vapours in Reducing Postharvest Rots and Effect on the Fruit Mycobiome of Nectarines. Journal of Fungi 10(5), 341. https://doi.org/10.3390/jof10050341

30. Remolif G., Guarnaccia V., Spadaro D. (2024) First report of nut rot caused by *Botryosphaeria dothidea* on almond in Italy. Plant Disease, 108 (11), 3414. https://doi.org/10.1094/PDIS-02-24-0482-PDN

31. Remolif G., Schiavon G., Garello M., Spadaro D. (2024) Efficacy of postharvest application of *Aureobasidium pullulans* to control white haze on apples and effect on the fruit mycobiome. Horticulturae. 10 (9), 927. https://doi.org/10.3390/horticulturae10090927

32. Ryalls J.M.W., Garratt M.P.D., Spadaro D., Mauchline A.L. (2024) The benefits of integrated pest management for apple depends on pest type and production metrics. Frontiers in Sustainable Food Systems, 8, 1321067. https://doi.org/10.3389/fsufs.2024.1321067

33. Waqas M., Guarnaccia V., Bardella S., Spadaro D. (2024) Molecular Characterization and Pathogenicity of *Diaporthe* Species Causing Nut Rot of Hazelnut in Italy. Plant Disease, 108 (4), 1005-1013. https://doi.org/10.1094/PDIS-01-23-0168-RE

OTHER PUBLICATIONS

34. Amico L., Guarnaccia V., Morando A., Morando N. (2024) Strategie efficaci contro la peronospora della vite. Informatore Agrario 13, 2024.

35. Bertetti D., Gilardi G., Valfrè P., Pugliese M., Garibaldi A. (2024) - Presenza di *Diaporthe eres* su *Viburnum opulus* in Piemonte. Protezione delle colture, 17 (4), 16-18.

36. Bertetti D., Gullino M.L., Garibaldi A. (2024) Nuovi problemi fitopatologici della colture ornamentali. Protezione delle colture, 17 (2), 2-5.

37. Bertetti D., Pensa P., Morlino M., Pugliese M., Garibaldi A. (2024) - Elmintosporiosi causata da *Bipolaris cactivora* su *Polaskia chichipe* in Italia. Protezione delle colture, 17 (4), 13-15.

38. Bosco S., Mezzalama M., Spadaro D. (2024) Fusariosi del riso, dalla diagnosi alla concia ecocompatibile. Informatore Agrario 80 (12), 34-36.

39. Carli C., Giordano R., Gilardi G., Gullino M.L., Garibaldi A. (2024) Lotta genetica e scelte agronomiche in programmi di difesa integrata di pomodoro e lattuga. Protezione delle colture, 17 (1), 20-25.

40. Carli C., Giordano R., Gilardi G., Gullino M.L., Garibaldi A. (2024) Lotta genetica e scelte agronomiche in programmi di difesa integrata di pomodoro e lattuga. Protezione delle colture, 17 (1), 20-25.

41. Dardani G., Guarnaccia V., Nari L., Testempasis S.I., Karaoglanidis G.S., Gullino M.L. Saggi di sensibilità ad azoxystrobin, ciprodinil, fenexamid, fludioxonil e tebuconazolo e caratterizzazione di ceppi di *Monilinia fructicola* e *M. laxa* isolati da drupacee in Piemonte. Protezione delle colture. 16(2). 14-15. 2023.

42. Gilardi G., Pugliese M., Carli C., Sanna M., Manunta A., Gullino M. L. (2024). Ortive, decisioni informate grazie ai DSS in campo. Terra e Vita 23, 44 – 47.

43. Gilardi G., Pugliese M., Garibaldi A., Gullino M.L. (2024) Pomodoro e lattuga, lo scudo dei microrganismi utili. Colture protette, Settembre (8), 47. -

44. Gilardi G., Pugliese M., Garibaldi A., Gullino M.L. (2024). Peronospora del basilico, misure di difesa e prospettive. Informatore Agrario, 18, 2-7.

45. Gilardi G., Pugliese M., Garibaldi A., Gullino M.L. (2024). Solanacee e cucurbitacee, gestione integrata dei patogeni. Informatore Agrario, 21, 46-50.

46. Gilardi G., Pugliese M., Gullino M.L., Garibaldi A. (2024) Impiego di microrganismi e prodotti diversi dagli agrofarmaci di sintesi nei confronti di patogeni critici di lattuga e pomodoro. In Protezione delle colture, 17 (1), 2-9.

47. Gilardi G., Pugliese M., Gullino M.L., Garibaldi A. (2024) Peronospora del basilico: aggiornamento sulla situazione in campo e sulle misure di difesa (2024). Protezione delle colture, 17 (2), 16-18.

48. Guarnaccia V, Dardani G. Malattie del legno della vite: la situazione in Piemonte. Vitenda 2024.

49. Guarnaccia V., Dardani G.; Di Marco S., Mugnai L. (2024) Malattie del legno della vite, osservazioni in Piemonte, L'informatore Agrario, volume 11(24), 58-61. 2024.

50. Guarnaccia V., Monchiero M., Talevi Paletto E., Spadaro D., Mezzalama M. (2024) Malattie del nocciolo, la difesa parte dalla corretta diagnosi. Informatore Agrario 80 (23), 2-4.

51. Gullino M.L., Gilardi G., Clini C., Garibaldi A. (2024) C'era una volta... il bromuro di metile (2024). Protezione delle colture, 17 (3), 5-13.

52. Gullino M.L., Monchiero M., Pugliese M. (2024) Vecchie e nuove avversità complicano la difesa delle colture frutticole (2024). Frutticoltura, https://rivistafrutticoltura.edagricole.it/difesa/oidio-ticchiolatura-marciumi-difesa-frutteto/

53. Gullino M.L., Pugliese M. (2024). Perché ci sono buone ragioni per non impiegare antibiotici nella lotta ai batteri fitopatogeni. Protezione delle Colture, 4, 2-5.

54. Martino I., Tabone G., Giordano R., Gullino M.L., Guarnaccia V., 2024. Disseccamenti del mirtillo causati da *Diaporthe eres*. Protezione delle colture.

55. Pugliese M., Garibaldi A. (2024) Ricerca di alternative agli agrofarmaci: successi e insuccessi della lotta biologica. Protezione delle colture, 17 (3), 17-21.

56. Pugliese M., Gilardi G., Gullino M.L., Garibaldi A. (2024) Prodotti innovativi per la difesa delle colture ornamentali e aromatiche (2024). Protezione delle colture, 17 (2), 11-15.

57. Talevi Paletto E., Remolif G., Martino I., Garello M., Nari L., Guarnaccia V., Spadaro D. (2024) Melo, malattie in post-raccolta, l'attenzione parte in frutteto. Informatore Agrario, 80 (37). 49-51.

ANNEX VI – Participation to national and international congresses

Congress	Place and date	Scientist	Title and type of presentation
Conference "Innovations in Food Loss and Waste Management"	January 23–25, 2024, Ancona, Italy	Davide Spadaro	Effectiveness of antagonistic yeasts and essential oils in the control of postharvest diseases of fruit – O
Conference "Innovations in Food Loss and Waste Management"	January 23–25, 2024, Ancona, Italy	Giulia Remolif	Screening and evaluation of antagonistic yeasts to control postharvest rots of strawberries. - P Efficacy of essential oil vapors in reducing postharvest rots of nectarines and effect on the fruit microbiome. - P Efficacy of antagonistic yeasts to control brown rot of nectarines and effect on the fruit microbiome. – O
Giornate Fitopatologiche 2024	March 12–15, 2024, Bologna, Italy	Davide Spadaro	Efficacia di agenti di lotta biologica e biofungicidi commerciali nel contenimento di patina bianca su mele in conservazione. - O
Giornate Fitopatologiche 2024	March 12–15, 2024, Bologna, Italy	Francesco Aloi	Un nuovo sistema di solarizzazione integrata per il contenimento dei patogeni tellurici negli appezzamenti di fragola. - O
32nd Fungal Genetics Conference	March 12–17, 2024, Asilomar, United States	Greta Dardani	Fungal diversity associated with grapevine trunk diseases in Northern Italy and development of a qPCR for the detection of Botryosphaeriaceae. - P
32nd Fungal Genetics Conference	March 12–17, 2024, Asilomar, United States	Micol Guaschino	A multidisciplinary, cross-species approach to understanding woody plant declines: similarities between Kiwifruit Vine Decline Syndrome (KVDS) and Apple Replant Disease (ARD). - P The key role of the biotic component in kiwifruit vine decline syndrome (KVDS) in Italy, an emerging multifactorial syndrome. - P
Conference Food System Microbiomes	May 14–17, 2024, Turin, Italy	Marco Garello	Validation of standard operating procedures for DNA extraction and microbiome analyses of soil samples. - P
13° Convegno dell'Associazione Italiana di Scienza	June 19–21, 2024, Turin, Italy	Simone Bosco	Selezione di endofiti di riso da utilizzare in strategie di lotta biologica contro *Fusarium fujikuroi*. - O

e Tecnologia dei Cereali			
XX International Plant Protection Congress	July 1–5, 2024, Athens, Greece	Davide Spadaro	Overview of postharvest disease management practices on apple: prevention, monitoring and control - I State of the art on the Kiwifruit Vine Decline Syndrome in Italy - O Post Harvest disease management of fresh produced with innovative and eco – friendly solutions - O
XX International Plant Protection Congress	July 1–5, 2024, Athens, Greece	Vladimiro Guarnaccia	Fungal pathogens causing trunk diseases in Northern Italy, species diversity and temperature interaction - I
12th International Mycological Congress (IMC12)	11–15 August 2024, Maastricht, the Netherlands	Vladimiro Guarnaccia	Fungal diversity associated with trunk diseases of apple and hazelnut in Italy - I A diverse community of pathogens of tree and vine crops is favored by increasing temperatures - I Organizer and moderator of the session "Effects of changing climate on fungal diseases"
XXIX SIPAV Congress	September 9–11, 2024, Trento, Italy	Ilaria Martino	"Mal dello stacco": a serious threat to hazelnut and preliminary attempts to develop biological control. – P
XXIX SIPAV Congress	September 9–11, 2024, Trento, Italy	Francesco Aloi	Effectiveness of a novel integrated solarization system to control soilborne pathogens of strawberry and effects on non-target microorganisms in Northern Italy. - O
XXIX SIPAV Congress	September 9–11, 2024, Trento, Italy	Simone Bosco	Microsatellite analysis of Italian isolates of *Pyricularia oryzae* over the years. - O
XXIX SIPAV Congress	September 9–11, 2024, Trento, Italy	Giulia Remolif	Efficacy of antagonistic yeasts in reducing grey mould of grapes and bioprotection activity in winemaking. - P Selection and evaluation of antagonistic yeasts in the control of strawberry postharvest rots and effect on the fruit microbiome. - O
IX International Postharvest Symposium	November 11–15, 2024, Rotorua, New Zealand	Davide Spadaro	Postharvest treatments with biocontrol agents and essential oils strongly modify the fruit microbiome - O New discoveries on emerging postharvest diseases of apples in Northern Italy - O

I = invited speaker
O = oral presentation
P = poster presentation

ANNEX VII - Outreach activities

EVENT	PLACE	SCIENTIST	Type of presentation	DATE
U*Night - Notte Europea della Ricercatrici e dei Ricercatori 2024	Torino (TO)	Massimo Pugliese, Giovanna Gilardi, Domenico Bertetti, Luca Alfarano, Carlo Roperto	Oral	September 29 2023
Monferrato Green Farm	Casale Monferrato (AL)	Massimo Pugliese	Oral	October 11 and 13, 2024
Monferrato Green Farm	Casale Monferrato (AL)	Monica Mezzalama	Oral-round table	October 12, 2024
UNIGHT - Notte Europea delle Ricercatrici e dei Ricercatori 2024	Torino (TO)	Davide Spadaro, Giulia Remolif, Greta Dardani, Andrea Manzoni, Elisabetta Talevi Paletto	Area Play	September 27, 2024
165° Fiera della Nocciola	Castagnole delle Lanze (AT)	Vladimiro Guarnaccia Monica Mezzalama	Oral-round table	August 26, 2024
The Saving Citrus Symposium	Florida, USA	Vladimiro Guarnaccia	Oral	July 25, 2024