ALMA MATER STUDIORUM
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DIPARTIMENTO DI
SCIENZE E TECNOLOGIE AGRO-ALIMENTARI

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Department of Agricultural and Food Sciences
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THE NEXUS APPROACH FOR SUSTAINABILITY OF WATER, FOOD & ENERGY - FINAL CONFERENCE OF DISTAL DEPARTMENT OF EXCELLENCE PROJECT (2018-2022)
Authors: *Massimiliano Petracci* & *Rosalba Lanciotti*

DISTAL is the Department of Agriculture and Food Sciences of the University of Bologna (ITALY).
The first event scheduled for the "Final Conference Departments of Excellence 2018-2022 - DISTAL" took place on June 1 in the form of webinar dedicated to the research projects of PhD students working on **Water-Food-Energy-Sustainable Agriculture Nexus** research topic of the PhD course in "*Agricultural, Environmental and Food Sciences and Technologies - STAAA*". The research topic was founded starting from the 34th cycle thanks to the funding "Departments of Excellence 2018-2022" with the aim of promoting innovative and multidisciplinary projects on the topics of sustainability in the agri-food sector. The webinar was opened by **Rosalba Lanciotti** (Department Head) and by **Davide Viaggi** (Research Delegate) who subsequently left the floor to **Massimiliano Petracci** (PhD Coordinator), who briefly illustrated the history and the current structure of the STAAA PhD course. The main part of the event involved the presentations by 8 PhD students who presented the progress of their research project starting from those enrolled in the 3rd (**Federica Barbieri** and **Margherita Del Prete**) and 2nd (**Eleonora Cappelletti**, **Beatrice Cellini**, and **Mara Petruzzelli**) years, respectively, while PhD at the 1st year (**Francesco Chioggia**, **Celeste Lazzarini**, and **Marta Reggio**) briefly presented the main objectives and the scheduled activities of their research projects. The webinar was attended by about 50 participants who appreciated the ability of the doctoral students to highlight the prominent points of their projects clearly and concisely and, above all, to emphasize the possible implications on agri-food production systems and society.
The main event of "Final Conference **Departments of Excellence 2018-2022 - DISTAL**" took place on June 9 in the Aula Magna of DISTAL and it was mainly focused on the presentation of the main results of the project "Dipartimenti di Eccellenza 2018-2022" funded by the Italian Ministry of Research and University in 2017 to boost the excellence of the Italian academic research. The event was opened by the greetings of the Rector of the University of Bologna, **Giovanni Molari**, who illustrated the path by which the 2018-2022 Department of Excellence Project was launched in his previous role as Head of DISTAL. Subsequently, Lanciotti and Viaggi presented the results achieved in the five-year period starting from the main aim of the project (i.e., the Nexus among Water, Food, Energy and Agriculture) to favor a sustainable and integrated management of the environment and its natural resources according to the circular economy principles. In fact, the project ambition was to contribute in an efficient way to face the global challenges and to achieve the main sustainable goals of UNESCO's 2030 agenda according with the regional, national, and international research calls and programs and the societal and industrial needs. Subsequently, **Claudio Ratti** (PhD vice-Coordinator) and **Alessandra Bendini** (Internationalization Delegate) illustrated the more specific aspects concerning respectively the activities related to the doctorate and internationalization.
A concomitant goal of the Project was to increase the international dimension of DISTAL both in educational programs and research synergic interaction and for this reason outstanding invited speakers such as **Nicola di Virgilio** (European Commission - DG AGRI), **Oliver Schlüter** (Leibniz Institute for Agricultural Engineering and Bioeconomy), **Ana Granados Chapatte** (European Forum of Farm Animal Breeders) presented the results of their research and their point of view on the circularity of the nexus linking agriculture, food, energy and water for sustainable production systems. The event was closed by the speeches of **William Meyers** (Food and Agricultural Policy, Research Institute, University of Missouri), **Wei Liao** (Michigan State University), and **Saverio Mayer** (Smurfit Kappa Europe) who acted as members of the external project evaluation committee.
The Conference was attended by 190 participants of which 160 attended in person and 30 remotely. It gathered national and international scientists, policy makers and stakeholders, gave raise not only to an update overview of the most innovative research results to increase the sustainability of agri-food production chains but also to an interesting discussion on future best tools to increase their impact on the globalized society. Presentations and photogallery available at the conference website.

The **Final Conference "THE NEXUS APPROACH FOR SUSTAINABILITY IN AGRICULTURE, FOOD, ENERGY & WATER**" and the **STAAA PhD OpenDay Dipartimenti di Eccellenza 2018-2022** were **partner events** of the **EU GREEN WEEK**.

ENGINEERING RESILIENT AGRI-FOOD SYSTEMS OF THE FUTURE

Authors: *Oliver Schlüter, Julia Durek and Shikha Ojha* (Leibniz Institute for Agricultural Engineering and Bioeconomy - ATB)

With the fast pace of world's population increase, it is projected that the human population will reach up to 10 billions by 2050, which will result in a significant **increase of the demand for food**. Feeding this huge population will put pressure on the limited resources such as agriculturally cultivable land. It has been projected that the food system in its current state could increase environmental impacts by 50–90% until 2050, if no mitigation measures are taken. Food insecurity in the face of climate change is a reality that calls for mitigating strategies to be urgently developed and implemented to ensure adequate quality and safe food availability for the present and the future. A swift global food transformation towards healthy diets supplied by sustainable food systems is necessary, and without such a transformation the world will not meet the targets set in the **United Nations Sustainable Development Goals** (SDGs) and the **Paris Climate Agreement**. In this regard, alternative and innovative ways to ensure sustainable supply of safe, nutritious, and high-quality foods are under investigation [1]. From a health perspective, a sustainable food system is a global challenge and needs to be considered alongside malnutrition, undernutrition, and obesity. Further, the role of food processing is inevitable in addressing the rising challenges of supplying sustainable diets for all people.

Dietary diversification is one of the most economically feasible, environmentally friendly and sustainable options to achieve a sustainable food system, which can take numerous approaches such as inclusion of varied food resources, some of which are underutilised or underexploited in the diet. **Edible insects** and macroalgae are high value **alternative protein sources**, exhibiting high quality nutrient compositions along with potentially **health-promoting constituents**. Insects can efficiently convert low-value by-products of food production into high-quality proteins, amino acids, fats, and vitamins, thus contributing to more efficient protein production and in turn enhancing sustainability of our food system by 'closing the cycle'. Interlinking the value chains of macroalgae and insects and focusing on a **zero-waste approach** for their holistic utilisation by employing **innovative food technologies** [2] could provide a sustainable approach towards developing **customised functional foods** with regard to a circular bioeconomy strategy (*figure 1*) and high consumer acceptance [3].

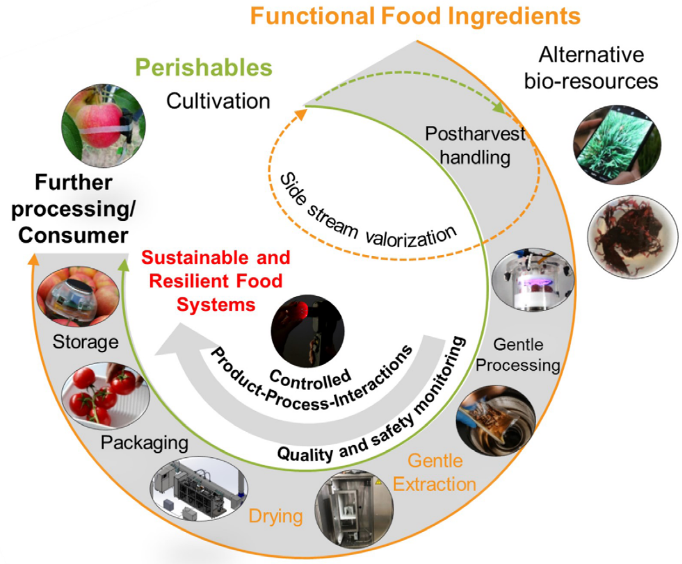


Figure 1: Integration of circular approaches from farm to fork into the ATB research on perishables and functional food ingredients. Utilisation of the side stream from food postharvest handling, processing and storage for obtaining functional food ingredients and alternative bioresources. Sensor-based quality & safety monitoring along the entire processing chain allows controlled product-process interaction to design sustainable and resilient food production systems.

Accordingly, the **Leibniz Institute of Agricultural Engineering and Bioeconomy** (ATB, *figure 2*) mission is to develop resilient and sustainable technologies for the resource efficient and carbon neutral utilisation of biological systems to produce **food, raw materials, and energy** in response to the challenges of climate change and changes in framework conditions on global scale. Main research fields are: i) environmentally sound and competitive methods of agricultural production, ii) the quality and safety of food and feed, and iii) renewable raw materials in rural areas or industrial feedstock and energy sources from biomass. At the Leibniz Innovation Farm, innovative concepts and technologies for a sustainable, circular bioeconomy will be developed and tested in the near future. The model farm will be established for this purpose. This farming will combine crop and livestock production with a research biorefinery with algae cultivation, insect breeding, natural fibre processing, biochemical production, and residue management with an integrated biogas plant.

Figure 2: Since 2019, the latest ATB research building CIRCLE has been expanding the infrastructure. CIRCLE stands for 'Center for Research and Communication in a Circular BioEconomy'. With 25 laboratories and 23 offices, the research building offers workplaces for about 60 employees, especially in the fields of microbiology and IT. A 330 m² dividable conference room, another two meeting rooms as well as a 125 m² cafeteria offer space for knowledge transfer and communication.

THE EUROPEAN TECHNOLOGY PLATFORMS TO FOSTER THE SUSTAINABILITY OF THE ANIMAL FARMING SYSTEMS

Author: *Ana Granados Chapatte* (FABRE TP)

The European Union has built over the years an extremely robust system to produce a common and sustainable framework for European citizens to live together. Twenty-seven countries and nationalities, with a variety of populations and visions, that have found a way to cohabit and build a common future. One of the essential roles of the European Union is to ensure **food security**, including the **affordability of food**. Europe has a long tradition of producing nutritious, safe, and qualitative food. To achieve this purpose, the farming community can rely on scientists that have developed a very impressive level of expertise linked to all the aspects of food production: from animal and plant breeding to nutrition and management practices. Then scientists and farmers have been able to respond to the **societal challenges** over the years to improve **food production**. These challenges have evolved and are defining new priorities for the farming community.

The level of expertise of the **food supply chain** is highly dependent on the resources that the European Union and Member States allocate to **Research and Innovation** (R&I). The needs are different depending on the societal challenges but also the context of production, the political situation, the climate conditions, the soils, the available resources and breeds, the tradition.

The European Union has developed **tools to invest in R&I**. However, we must make aware policy makers about the needs of the scientific and the farming communities in EU in terms of gaps for R&I and areas in which we must improve knowledge. For this reason, it is fundamental to continue and even increase funding for agriculture research.

[FABRE TP]() is one of the 6 active **European Technology Platforms** (ETPs) in the Food R&I sector. Together with other ETPs, we explain which are the needs on research and to increase knowledge towards more sustainable food production. ETPs have the capability to connect the private sector with academia and other research institutes across the EU and partners countries. ETPs are networks of scientists who can also contribute to **build science-based legislation**.

FABRE TP connects animal breeders with the research community. It supports innovation and makes policy makers aware of the role of **animal breeding** to support animal farming and to improve the **sustainability** of different farming systems. FABRE TP represents a small sector that is not well-known by citizens and policy makers. Explaining the role of scientists and of the sector is crucial. The collaboration with the rest of the platforms is fundamental to achieve progress all together. Animal breeding and farming are currently under pressure and scrutiny by politics and the society. This raises more than ever the need to collaborate within and outside the genetics and reproduction community. Animal sourced products are more than proteins and part of sustainable farming systems and diets. The role of FABRE TP and other ETPs is then to **connect science with society and politics**.

GLOBAL RURAL POLICIES IN A COMPLEX WORLD

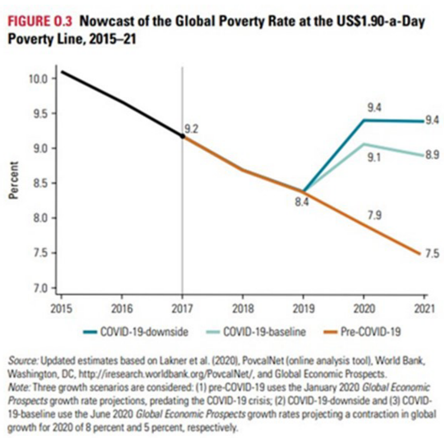
Author: *William H. Meyers* (University of Missuri)

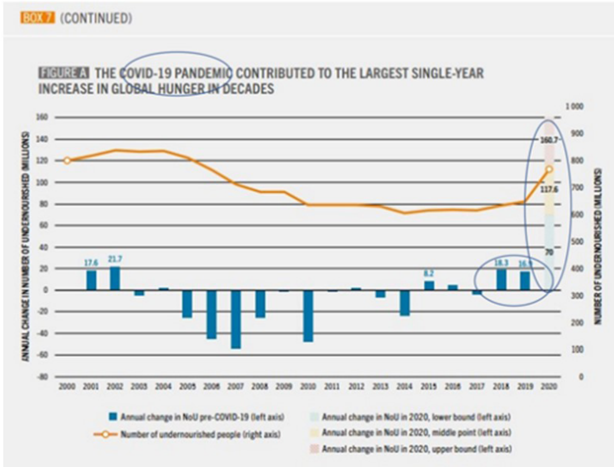
Global rural policy has merged in my view with agriculture and food security ever since my time at FAO, when we stressed that most of the poor and food insecure in the world were rural people and often working in agriculture themselves. How ironic that many of the food insecure are actually food producers that are lacking in the resources even to feed themselves. At the time, even development agencies were neglecting basic agricultural issues that have since become front and center in the global **sustainable development goals** (**SDGs**).

So I begin with the concept that priority should be given to those programs that can help achieve multiple SDGs simultaneously as called for in the World Social Report 2021-22. These include comprehensive public investments directed at:

- Improving basic infrastructure (including roads, electricity supply, clean drinking water and sanitation facilities);
- Human capital development (including quality education, healthcare, cultural facilities);
- Adequate provision of public administrative services; and
- Broad-band Internet and other information and communications technology services.

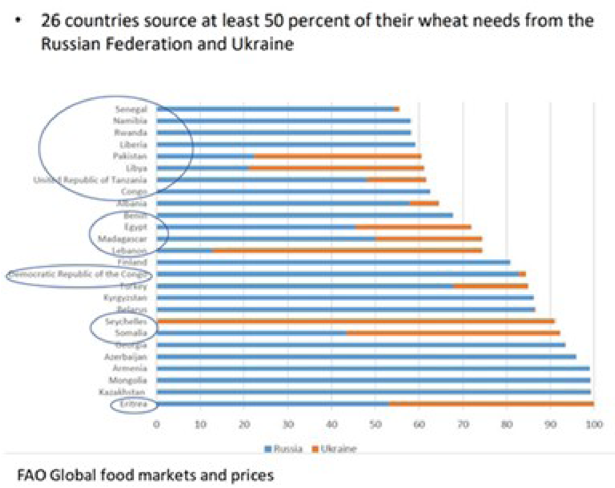
Rural space is where most poverty and food insecurity exist (FAO 2000). But what about the **4 Cs** (i.e., **Climate**, **Conflict**, **Covid-19**, and **Cost**)? What about the *context* for Development? **C**limate and **C**onflicts have long been recognized as central to the incidence of poverty and food insecurity. Then came **C**OVID-19 and **C**ost inflation that thrust the world, and especially the poor and food insecure populations, into a rapid reversal of the progress that was being made in reducing poverty and food insecurity in the world.





Now our attention has been thrust into the Russian attack on Ukraine, which is like **a Black Swan on the Black Sea**. Many previous conflicts had mostly local or regional impacts, which were very serious in the regions they impacted; but this conflict has disrupted global food and fertilizer markets in a way that has widespread impacts on prices and trade across the world and especially in countries and regions that are already food insecure.

In particular, before the war, Ukraine was expected to provide 14 percent of global exports of grains (excluding rice), second only to the United States. Moreover, Ukraine and Russia together have been providing more than 50 percent of wheat to many of the food deficit countries in Africa and the Middle east. While countries can likely find other suppliers, they will be more distant and more costly to obtain, such as from Brazil and Argentina.



The disruption of trade caused by Russia's war on Ukraine has also caused prices to increase in the short term and is even destroying grain and oilseed stocks in Ukraine as well as causing severe disruption to harvest of winter wheat and planting of spring crops. Longer term damage to Ukraine's deep black soils is also being deliberately done with bombing campaigns.

The world is looking for short- and longer-term solutions to this crisis. Of course, the priority is to stop the war. Next is to open Ukraine ports so that stored grain that is now blockaded can be shipped. Another important action is to stop hoarding grains and oilseeds, which some countries have tried to do just to protect their own markets. Restoring peace and normalcy to Ukraine and the world trading system is the highest priority so that we can return to the longer-term challenge of global rural development and food security.

SUSTAINABLE ENERGY SOLUTIONS FOR SUSTAINABLE AGRICULTURE

Author: Wei Liao (Michigan State University)

Sustainable energy is one of seventeen goals for global sustainable development that were established by the United Nations in 2015.

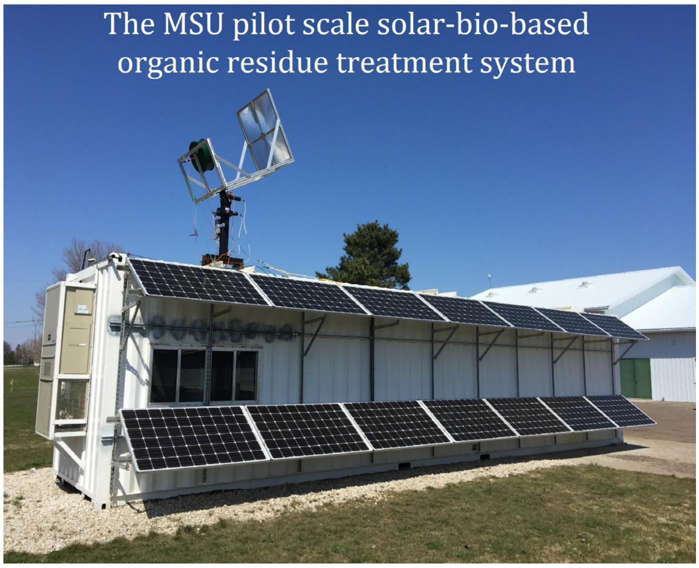
Progress has been made on the **global energy sustainability** goal in the past decades. However, the rates of increase are still not fast enough to achieve the goals. The share of global renewable energy in total final energy consumption (TFEC) reached 17.3% in 2018; while, reliance on traditional biomass burning in some regions such as Sub-Saharan Africa accounts for almost 85% of its **renewable energy consumption**, which leads to **adverse health and environmental effects**.

Energy efficiency as another key target is measured by global primary energy intensity, which needs to be doubled by 2030. To achieve the goal, a growth rate of 3.6% on primary energy intensity is required. Therefore, new strategies and solutions need to be developed in a timely manner to facilitate achieving the energy sustainability goal. **Agriculture and rural development** could play a **pivotal role** in this.

Michigan State University Campus

Agriculture needs to increase food production to match **growth rate of the population**. The world population increased from 6 billion in 2000 to 7.8 billion in 2020 and is projected to exceed 9 billion by 2050. Concurrently, the global middle class is projected to grow from 50% to 70% due to increased earnings and will approximately double the food demand by 2050. If humankind continuously uses **conventional farming practices** that depend on singular crops, fossil-fuel-based fertilizers and pesticides, and conventional post-harvest and food processing practices, global agriculture and food systems will consume more than 30% of the world's available energy, and produce over 20% of the world's **greenhouse emissions** to satisfy such an increase. On the other hand, such a massive increase of food demand provides global agriculture and rural communities an opportunity to develop **next-generation farming practices** that could synergistically address food, energy, and water challenges.

Demonstration scale anaerobic digestion and algae cultivation facility at MSU



The MSU pilot scale solar-bio-based organic residue treatment system

Next-generation agriculture needs to integrate food production and renewable energy generation into a system. Foods, **crop residues**, **food wastes**, and **marginal lands** also need to be considered as a system for both **food and renewable energy production**. For instance, if all global crop residues and food wastes could be collected and utilized for renewable energy production, the renewable energy generated (180 exajoules per year) could satisfy the energy demand of the entire global agriculture and food production, and sequester more than 15% of the world's greenhouse emissions. It is apparent that such integration will systematically address energy security, food security, climate change, and economic development, which will facilitate achievement of the energy sustainability goal.

DELIVERING ON THE EU GREEN DEAL: SMURFIT KAPPA'S VISION OF PACKAGING TO BE TRULY CIRCULAR

Author: *Saverio Mayer* (Smurfit Kappa Europe)

Without packaging we cannot imagine today's world, where products travel through global supply chains lately even directly to our doorstep. Packaging is a service to a product, it bundles and protects the product, informs consumers about the product, and it should not become a global waste challenge at the end of its useful life.

The European Green Deal aims to stop climate change, enable circular economy to tackle resource efficiency and avoid pollution inside and outside Europe.

What does that mean for packaging? All **packaging** will have to become **climate neutral** (produced with clean energy), **avoid leakage to the environment** (keep resources in the economy) and **biodegradable** at the final end-of-life after multiple reuse, recycling cycles (do not pollute).

In Smurfit Kappa we have developed **a 3-step roadmap to deliver packaging innovation** for today, tomorrow, and ultimately in 2050.

- First step – reduce packaging problem in general, making it circular by design. Use packaging only when needed, ensure right amount of packaging, employing sustainable materials and ensure fit-for-purpose packaging design. Perfect packaging is not big or small. It is just enough and nothing more.
- Second step – limit packaging problem making it circular by humans. When fit-for-purpose packaging is developed, we, humans, need to ensure it is circulating in the economy as long as possible. Using strategies like packaging reuse, repair, recycle, remanufacture, employing infrastructures that work in practice and at scale, we ensure resource circularity. For example, paper-based packaging is collected and recycled at the highest rates compared to any other packaging - latest statistics of Eurostat shows 92% collection and 82% recycling of paper-based packaging in EU (2019).
- Third step – solve packaging problem making it circular by nature. Packaging should be produced from renewable sources (to avoid scarcity, depletion of resources) and when it reaches its natural limit and final end-of-life (after multiple use, reuse and recycling cycles) it should biodegrade naturally into nature without pollution.

In a summary - material is taken from nature, made into a product such as packaging, reused and recycled as many times as possible, and ends up back in nature where it should biodegrade, in sympathy with the nature-to-nature cycle. This must all happen without any pollution and emissions. In the long-term any packaging, that cannot fulfill this, is not a viable solution.

This is a very ambitious agenda, and a lot must be done in each step of the roadmap by packaging producers, like Smurfit Kappa and packaging users (brand owners, retailers, even consumers). At the same time, it opens a world of opportunities to reimagine packaging role and demands disruptive innovations.

In Smurfit Kappa we launched Better Planet Packaging initiative to focus on developing **more sustainable packaging solutions** using 3-step roadmap. To name a few examples:

Smurfit Kappa
Better Planet Packaging

- paper-based punnets for fruits, vegetables, berries, etc. White or brown, closed or open, printed or not - is a perfect example of natural packaging choice for natural products.
- paper-based buffers to replace expanded polystyrene (EPS) buffers, allow mono-material, recyclable and recycled packaging solution for small or big electronics, furniture, ceramics, appliances, etc.
- paper-based parcels for eCommerce sales channel are today's reality to deliver even most fragile products, like glass bottles with absolute security (ISTA certified, FFP compliant).

These are just few examples, and our bigger ambition is to supply the world with Better Planet Packaging solutions making a positive impact on billions of supply chains and consumers, while improving the packaging environmental footprint and reducing packaging traces on the planet.

For more info visit www.smurfitkappa.com

FORESTS AND GLOBAL CHANGE: EFFECT OF AIR POLLUTION ON TREE WATER-USE EFFICIENCY AND FOREST NUTRIENT LIMITATIONS

Author: *Alessandra Teglia*

Forests are widely recognized as **important carbon sinks** as they contribute removing up to 25% of CO_2 emitted from anthropogenic emissions, thus representing a nature-based solution to **mitigate climate change**.

Global change pressures (e.g., climate and land-use changes, intensification of climate extremes, increasing atmospheric pollution, particularly in the form of reactive nitrogen), however, undermine their capacity to continue providing important ecosystem services, including climate change mitigation, clean water and air supply, food and energy production, and improvement of human health and well-being.

Most of the reactive nitrogen input to terrestrial ecosystems comes from anthropogenic activities, such as intensive use of chemical fertilizers, fossil fuel combustion from industrial activities and transport. Increasing nitrogen input from **atmospheric deposition** can enhance nitrogen availability, thus promoting tree growth and **forest carbon sequestration**, particularly in the case of **nitrogen-limited temperate forests**. However, excess of nitrogen can negatively affect tree health, forest biodiversity and lead to eutrophication. Climate change is already changing rainfall patterns. Forest ecosystems in Italy have been experiencing reduced water availability and extreme heat over the recent decades. Understanding how different global change components interact and affect **forest functioning** is crucial for predicting forest adaptation, resistance, and resilience to climate change.

My PhD research project focuses primarily on atmospheric pollution, such as nitrogen deposition, and its effects on forest ecosystems health and functionality.

To this aim, a manipulation experiment was established (within a MIUR-PRIN grant) to simulate increases in atmospheric nitrogen deposition on two beech forests in Italy at contrasting climatic and atmospheric deposition conditions. A first study on **foliar nutrients** at both sites (Teglia et al. 2022) indicated that nitrogen addition alters nutritional status, with reduction of some macronutrient (e.g., phosphorus, potassium...) in the most polluted forest site. The next step will be to elucidate whether nutrient alteration affects **tree water-use efficiency** (the ratio between photosynthesis and transpiration), and to assess modifications in the tree–ectomycorrhizal fungi relationship, which is crucial for tree nutrients and water uptake.

BIO-FORMULATES AS A PROMISING CONTROL STRATEGY AGAINST DIFFERENT *FUSARIUM* PATHOGENS TO REDUCE FOOD MYCOTOXINS CONTAMINATION

Author: Eleonora Cappelletti

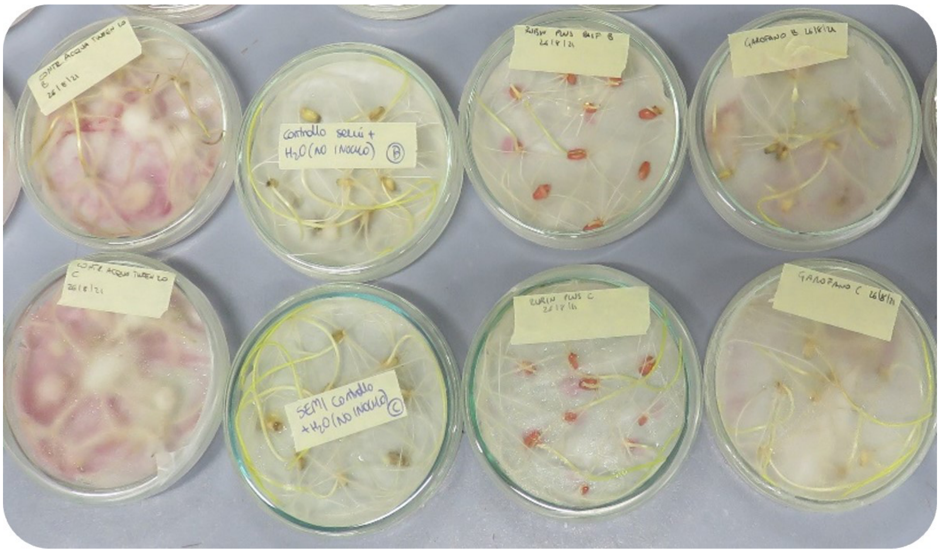
Durum wheat is one of the world's most important food crops used in the preparation of a wide range of products, including pasta and bread. Italy is one of the main producer and consumer of this cereal, that unfortunately is susceptible to the attack of microorganisms responsible for different diseases causing both quantitative and qualitative damages.

The main fungal species involved in the process belong to the **genus *Fusarium***, namely *F. culmorum*, *F. graminearum* and *F. pseudograminearum*. These fungal pathogens, besides causing huge yield losses, are responsible for the production of high levels of a wide variety of mycotoxins. Mycotoxins are secondary metabolites that, if present in high concentration, can cause both humans and animals food poisoning. Specifically, two main diseases that affect durum wheat in the early stages of development are *Fusarium* Foot Rot and *Fusarium* Crown Rot. The species involved in these diseases can act alone or in combination, affecting the root and the internodal portion of the culm, respectively. Infected seeds decrease the germination rate, slow the emergence, and cause a post-emergence blight of the seedling. All these problems are kept under control thanks to defense strategies based on good agronomic practices, healthy seeds and the use of chemical seed coating, a technique that creates a physical barrier capable of protecting the seed from external pathogen attacks.

Basal browning of durum wheat due to the infection of *Fusarium* species

Since sustainability nowadays is fundamental, the research must be directed on finding effective alternative strategies to pesticides, especially for organic farming. It is precisely here that my **NEXUS PhD project**, focused on sustainability in agriculture and food, fits in. There is a deep need to find more sustainable approaches, aimed at reducing the use of synthetic agrochemicals and preserving the ecosystem and the environment.

The use of **natural products as seed coating** may represent a valid alternative strategy to defend crops in the near future. Organic seed coating technique with endophytic bacteria and/or essential oils may represent a reliable and safe strategy able to control soil-borne pathogens. To select potential biocontrol agents against *Fusarium* Foot Rot and *Fusarium* Crown Rot diseases of durum wheat, it was tested the antagonistic effect of several **beneficial bacteria** and several types of **essential oils** on the growth of different species of *Fusarium*.



Durum wheat seed coating *in vitro* trials

The most promising results were obtained with *Lactobacillus* strains and essential oil of carnation and thymus. Furthermore, we are testing their efficacy directly applying them as a seed coating against different *Fusarium* strains.

Coming to final consideration, the expected result of my PhD period is to identify an environmentally friendly defense strategy using biological coating. The purpose is to find an effective and stable formulation based on microorganisms, substances produced by them and/or essential oils, to reduce the use of synthetic chemicals in the field and, at the same time, to be able to **reduce the risk of mycotoxin contamination in food**.

MICROBIAL BIODIVERSITY AS A NEW GREEN AND SUSTAINABLE SOLUTION TO ENHANCE FOOD SAFETY & REDUCE AGRI-FOOD WASTES IN THE NEXUS APPROACH

Author: *Federica Barbieri*

The actual global population growth drove energy and food resources towards an ever-stronger pressure. In recent years, an always increasing amount of **food wastes**, also related to **microbial spoilage**, resulted in a loss of food quality and microbiological safety. A strategy to reduce this safety concern and the corresponding food loss is represented by Nexus approach, that promotes the reduction in food waste and the optimisation of the production yields by using energy in a sustainable way. Moreover, the widespread consumers demand for natural and innovative foods directed the research towards the study of **new green and sustainable solutions**, such as **bio-preservation** and **bio-protection**.

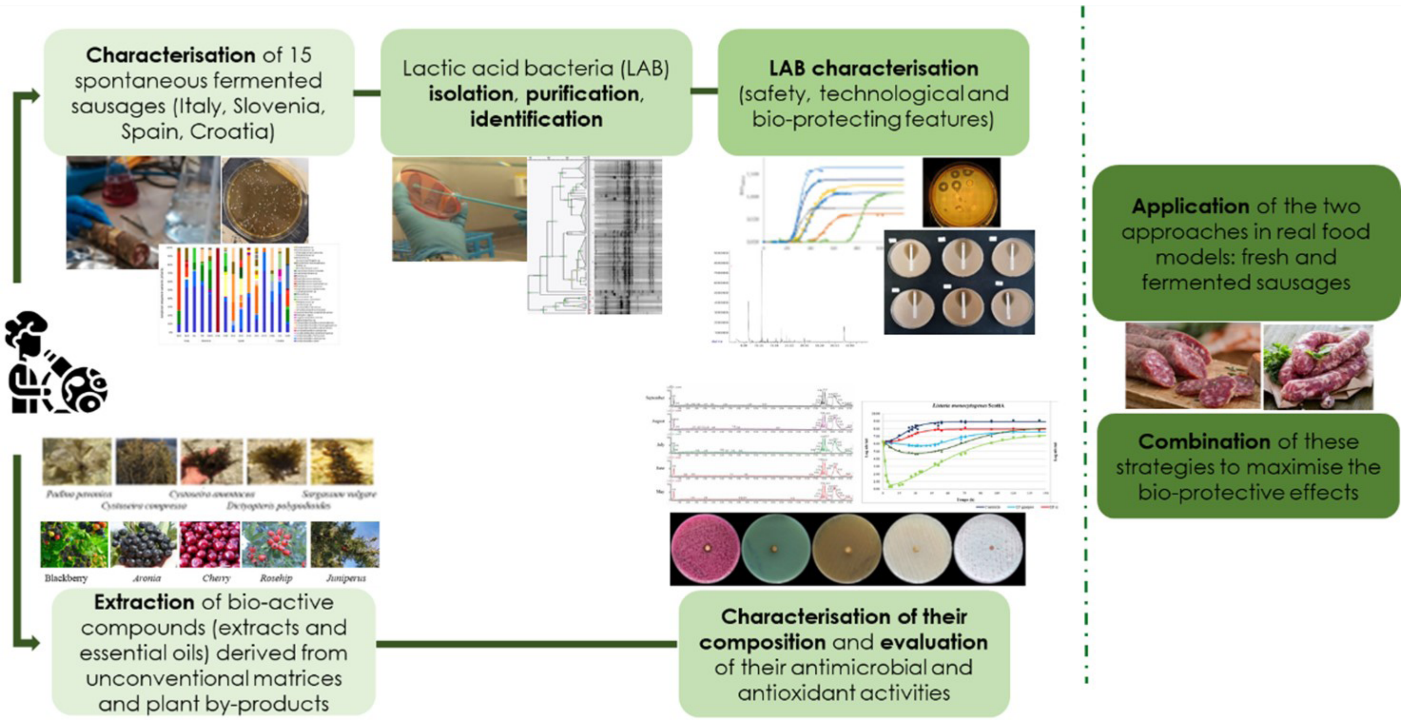
Given these considerations, the three years of my PhD thesis were focused on the study and development of innovative strategies to improve the quality and microbiological safety and extend the shelf-life of fresh or fermented products. Moreover, this research project was part of the **PRIMA project**, financed in the frame of Section 2 - 2019, titled BioProMedFood, that intended to provide **innovative low-cost solutions for local food chains** and promote **environmental sustainability of food productions**.

To achieve these goals, bio-active natural compounds, obtained from plant by-products or unconventional matrices (*i.e.,* brown algae), and bio-protective cultures, isolated from traditional naturally fermented sausages, were used for the valorisation of **Mediterranean biodiversity**.

Bio-active compounds were employed for their strong antimicrobial and antioxidant activities, while the mitigation of microbial spoilage and safety concerns was achieved by using **lactic acid bacteria** strains, due to their competition with spontaneous microbiota and foodborne pathogens and their ability to produce specific antimicrobial metabolites. Several spontaneous fermented sausages, collected from Italy, Slovenia, Spain, and Croatia, were used as a source of isolation of these autochthonous strains, representing an important cultural heritage of microbial biodiversity linked to the origin area.

The core of the project was represented by their screening for safety and technological features to select the best candidates to be applied in real food systems to achieve safety and food quality and to preserve product peculiarity. In fact, the typical characteristics of the traditional products can be impoverished by the application in the meat industry of commercial lactic acid bacteria strains as starter cultures, due to their limited number and standardised applications.

Thus, to guarantee food safety and environmental sustainability of agri-food systems, different **possible solutions** are available, such as the valorisation of traditional foods, with the aim to find new bio-protective or functional strains, and, on the other hand, the use of unconventional matrices and by-products as a source of bio-active compounds to reduce food wastes. These two strategies could be applied, also in combination, in food industry to maximise the bio-protective effects and **extend shelf-life of perishable foods**, maintaining their peculiar nutritional and organoleptic properties and reducing microbiological risks.



AGRICULTURE-CLIMATE-MARKET NEXUS IN COMPLEX DYNAMIC FRUIT MARKETS
Author: Zeeshan Mustafa

Crop production, marketing, and environment undergo interactions like any other ***complex system***. These interactions are hitched in time and space and subject to uncertainty that generates unpredictable (chaotic) fluctuations (volatility). The modern **model-centric approaches** failed to accurately predict the 2007/08 global financial and food crisis. This failure has laid stress over finding new avenues of research to look for causality behind apparently chaotic systems.

The present research was aimed at studying the fruit-chain dynamics of three countries, i.e., Brazil (South America), Italy (Europe), and Pakistan (Asia), each with different management strategies to dump such fluctuations. The *agriculture-climate-market nexus* was studied through the **nonlinear time series (NLTS) approach**. We have summarized all the steps involved in applying *NLTS* analysis in **Figure 1**.

The observed time series of fruit production, prices, and temperature were graphically converted into a signal (shape of its graph as a function of time), and noise (measurement errors) was removed. The greater than 50% signal strength indicates that the generated series' explosive nature (chaos) can be predicted (determined).

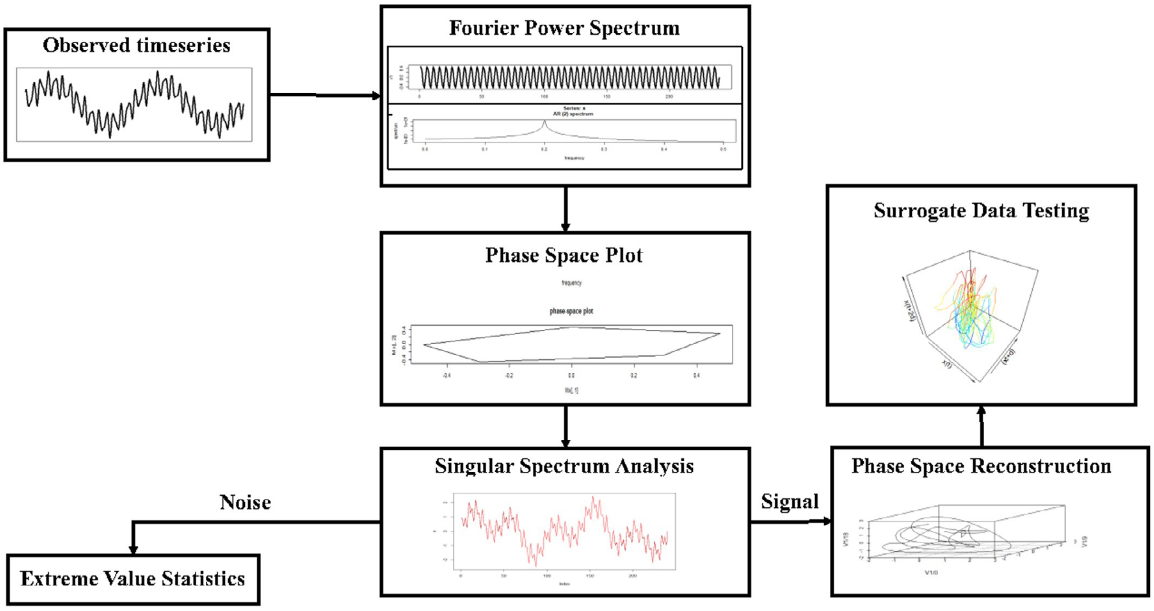


Figure 1: Schematic diagram of conducting nonlinear time series analysis (NLTS)

The cleaned signals have been plotted in *3D* view (phase space), where time disappears, and curves represent the trajectories of the three state variables or their lagged version during the time. Cycling represents seasonal fluctuations and always has a similar shape (*attractor)*.

The preliminary result of *NLTS* analysis on nectarine and peach production in *Emilia Romagna (ER) region* (Italy) shows that fruit production exhibits a strong signal extracted from their time series. The cyclic curves of the two fruits production show (**Figure 2**) that curves are attracted towards a single point (of equilibrium). Points of nectarine and peach production are stable and unstable as they are moving towards and away from equilibrium, respectively. The peach attractor may have a multi-scroll (loops) attractor with another stable equilibrium as the line separates away (another loop) from the thick black lines at the horizontal axis around (x=-0.4, y=-1.4). Similar results were also reported from prices and temperature variables.

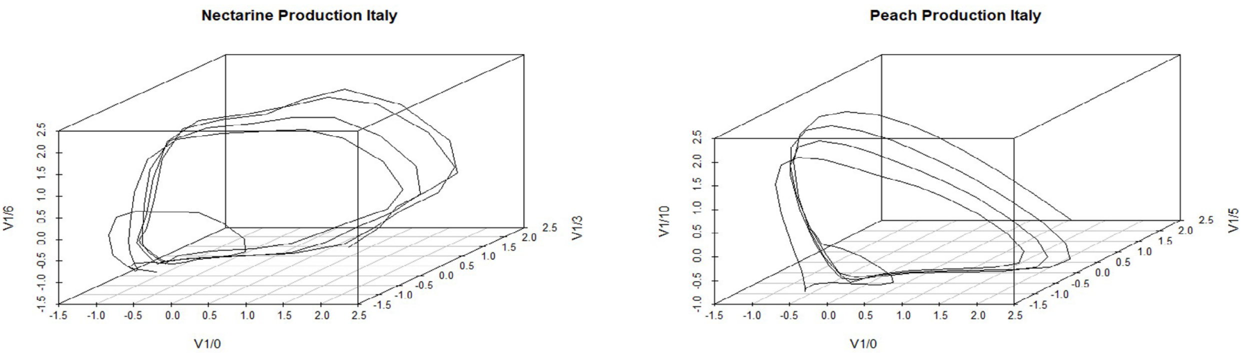


Figure 2: Phase space reconstruction of nectarine and peach productions in Emilia-Romagna, Italy

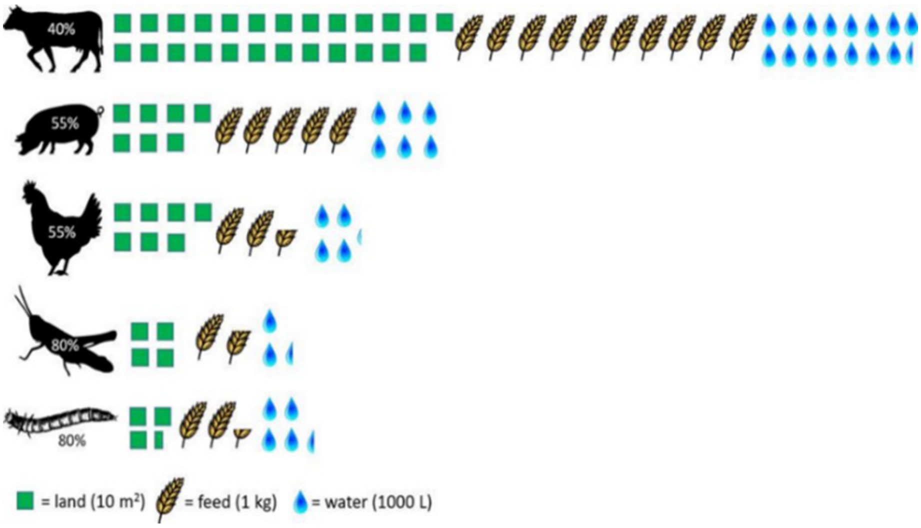
In conclusion, the study proved that *fruit market dynamics* are deterministic. In such systems, **markets are inherently unstable**, and government policy can profitably intervene to reduce price volatility affecting both consumers and producers.

INNOVATIVE BAKERY PRODUCTS OBTAINED WITH HYDROLYSED CRICKET POWDER

Author: Samantha Rossi

Edible insects are over 2000 species and the entomophagy, the eating of insects, is exercised traditionally in 113 countries all over the world. Insects are a valid food resource as they have a well-balanced nutrient profile, in terms of amino acid, high polyunsaturated fatty acids, micronutrients and vitamins. Insects are also valued for their functional properties and their potential application as protein-rich meat replacing ingredients.

Insect farming is more environmentally friendly than livestock in terms of greenhouse gas production, water consumption and soil requirements. However, their use is still limited in the European culture because insects are not part of their **alimentary diet model** and are **not well perceived**. For this reason, it is necessary to improve the image of edible insects, with the use of powders or flours in familiar products such as biscuits, bread, and crackers to increase consumer acceptance.



In this perspective, three yeast strains were used separately to produce cricket powder-hydrolysed characterized by a **reduced content in biogenic amine and chitin** (responsible for toxicological effects with various degrees of severity), presence of **antimicrobial substances** (chitosan and short chain fatty acids) and **health-promoting molecules** (linolenic and arachidonic acids).

The hydrolysed obtained from *Yarrowia lipolytica* PO11, RO25 and *Debaryomyces hansenii* SP6L12 were used as ingredients for innovative bread production. The obtained results showed the capacity of the strains to differently characterize cricket powder-hydrolysates due to the different growth potential, specific proteolytic activities, and different production of volatile molecules. Specifically, *Y. lipolytica* RO25 demonstrated high ability to reduce the biogenic amine content and to degrade chitin, thus **reducing health hazard**. Furthermore, the results highlighted the significant proteolytic activities of the tested strains which increase the matrix digestibility and the release of essential amino acids such as histidine, threonine, leucine, and ornithine.

The obtained doughs were also qualitatively different and characterized by **specific fingerprinting** due to the well know proteolytic and lipolytic activity of *Y. lipolytica*. In fact, free fatty acids and free amino acids were volatile molecules precursors that improved the sensory features of the raw material due to the production of **many aroma compounds** characteristic of ripened and fermented foods.

Finally, all the cricket based-bread formulations, with a few exceptions, received **positive judgments** during the sensory analysis, demonstrating how the hydrolysates used, in relation to the strain considered, can impart specific physicochemical, functional, sensory, and qualitative characteristics to the final product. This is a good prospect for a **future scale-up production**. However, many factors are still to be taken into consideration, including the **allergenic potential** of the cricket powder. Few studies exist on this topic and mainly case reports on **primary sensitization against insects** are provided. For this reason, in collaboration with Leibniz Institute for Agricultural Engineering and Bioeconomy and Paul-Ehrlich-Institute (Germany), the evolution of the allergenic potential of cricket powder in relation to the biotechnological process used during food production was recently studied and the results are being processed.

LEGUME-BASED ROTATION IN LOW INPUT AGRICULTURAL SYSTEMS

Author: Camilla Tibaldi

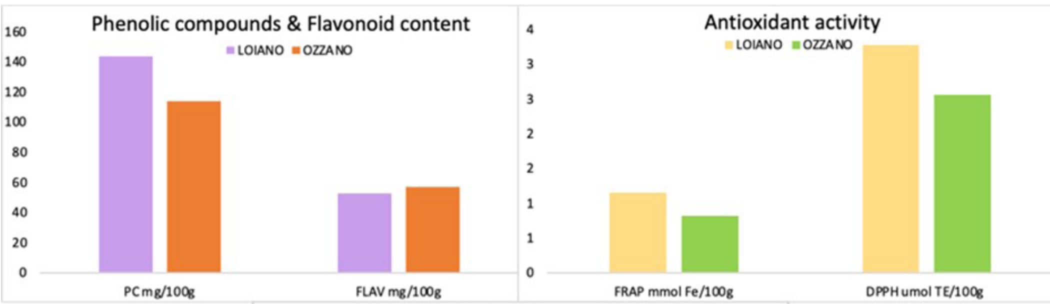
Over the last decades, the consumers interest in **alternative protein** sources to meat has increased worldwide. This behavior is driven by the preservation of good health, environmental sustainability, and animal welfare.

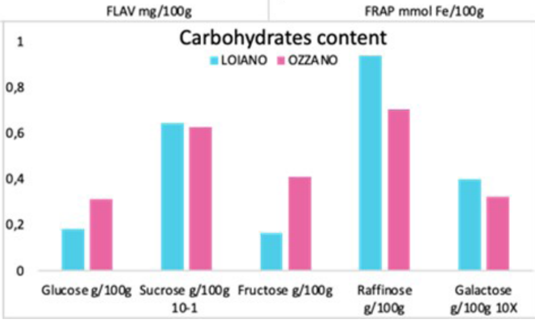
Legumes represent one of the largest sources of **plant-based meat alternatives** and, among them, **peas** (*Pisum sativum* L.) may be identified as nutritious and sustainable protein substitutes. Besides being an important source of high-quality proteins, peas contain high levels of dietary fibers, resistant starch, vitamins, and minerals, as well as health promoting antioxidants. In this perspective, the revitalization of grain legume cultivation for fodder and human nutrition could provide an important contribution to the emergence of **low-input production** direction, favoring greater integration between plant and animal production. My research aimed to evaluate the agronomic performance of protein alternative crops (pea grain) in the Italian environment in the Emilia-Romagna region under low-input cropping system and included in a **three-year rotation plan**. In parallel, nutritional and health characteristics for human health of pea crop was investigated.

Field trials consisted in the cultivation under organic conditions of 4000 m^2 with one variety of pea (*Pisum arvense* L. var. Turris) as pure stand and 1000 m^2 with a mixture of three different varieties of pea (*Pisum arvense* L. var. Turris, *Pisum sativum* L. var. Navarro and var. Bruno). The experimental fields were in Loiano and in Ozzano dell'Emilia. Winter and Spring sowing were chosen for Loiano and Ozzano field, respectively.

Preliminary results showed that **winter-sown peas** (Loiano) exhibited **higher agronomical traits** compared to spring-sown peas (Ozzano), thanks to a longer period of accumulating biomass, and a more effective utilization of spring precipitation, as well as a better developed root system in early spring. On the other hand, it was observed a significant higher grain biomass yield in Ozzano. This unexpected result was related to an excessive presence of weeds and high incidence of wild animals in the field of Loiano during the vegetative development of the plant.

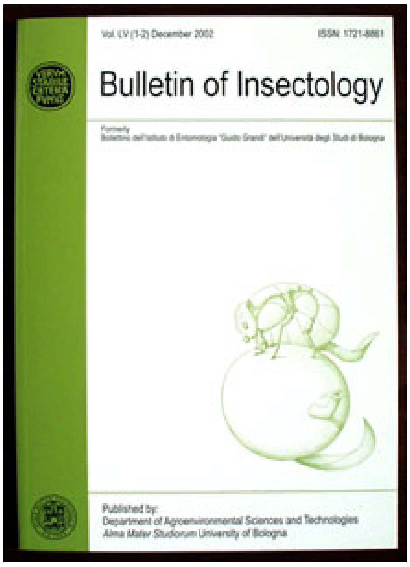
Regarding nutritional analysis, Loiano samples showed the highest level of **polyphenols** and **antioxidant activity**. This trend may reflect plant response to specific abiotic stresses of the growing environment, as occurred in Loiano field. However, the highest values of glucose and fructose content were registered in Ozzano grain, whereas no significant difference of sucrose was observed between the two sites. Nonetheless, the content of raffinose was significantly higher in Loiano peas, due to its role in the cold acclimatization of plants, explaining its high content in winter-sown peas. For all the agronomical traits and nutritional features, no significance was observed between the pure stand and the mixture of peas.





The present data showed that **location may affect the agronomic and nutritional characteristics of pea** crops. Nevertheless, these results are representative of only 2021 crop cycle. Additional data coming from one more year of experimentation will give additional insights.

EDITORIAL ACTIVITIES



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