Waitrose

COLLABORATIVE TRAINING PARTNERSHIP

2017 to 2025

Contents

With Thanks

The Collaborative Training Partnership (CTP) would not have been possible without the financial, organisational and scientific support of our project partners. We wish to extend our sincere thanks to each of our partners.

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Vision

When Alan Wilson from Waitrose first approached me about the prospect of establishing a BBSRC Collaborative Training Partnership between universities and the Waitrose Agronomy Group I was incredibly excited. The partnership represented an opportunity to bring together academics and industry to work together in a way which was new for those of us working in food security. We brought together three universities, Lancaster, Reading and Warwick. We also welcomed the research institute Rothamsted Research to the partnership. All of us had long-established relationships with Waitrose and their fresh produce suppliers so this project represented an amazing opportunity to build upon existing collaborations but also to build new ones. The funding, from BBSRC and the Waitrose Agronomy Group, was specifically to train a new generation of PhD students, students who by the time they finished their degrees would be equipped to face the multidisciplinary challenge that food security represents, as well as having a good understanding of the fresh produce industry.

Our students all had projects that were developed in partnership with a supervisor working in industry. Through a careful project selection process that matched academics with industry partners we ensured that all of the projects were directly relevant to the sustainable production of food and the questions that those working in the fresh produce industry needed an answer for. This led to some exciting applied research questions being asked and lots of novel science. All of our students had a supervisor working in the fresh produce industry, they spent time with suppliers in their place of work, and they all heard from many different people working in different areas of food production.

Ultimately I believe we were very successful, not least of course, due to the commitment and hard work of the fantastic students you will hear from in this brochure. Our students have gone on to a range of different destinations working in industry, government and academia so all are putting the skills they learned to good use.

Carly Stevens Lancaster University

Lancaster University

Dom Stevenson

Based at:
Lancaster University
Industrial Partner:
APS Group

Can Inherited Memories of Stress Help Protect Crops from Pests and Disease?

My project studies the use of "priming" as an alternative to chemical control of pests and disease. Due to various concerns about pesticides damaging the environment and residues on food, there is increasing pressure to look for alternatives for protecting crops from pests and disease. One such alternative is 'priming'. Priming is a phenomenon by which, following an initial exposure to pests, plants are able to launch stronger defence responses to pests in the future. The aim of this project was to investigate whether chemical elicitors can be used on parental tomato plants to produce primed seed that have characteristics beneficial to growers.

- Several commercially available plant defence activators, alongside other well-known elicitor compounds, were used to generate lines of seed from treated parent plants.
- By giving parent plants a priming treatment, the next generation of plants are better able to resist future challenges like disease and pests.
- Transgenerational immune priming in plants will be an important way of reducing the hazards posed by pests and diseases without the need to rely on pesticides.

How were your findings relevant to food security challenges?

By demonstrating the potential of chemical elicitors to prime disease resistance in crops, my research contributes to reducing pesticide reliance and fostering sustainable agricultural systems. This approach offers a pathway to protect yields in the face of evolving pest pressures.

Alex Bleasdale

Based at:
Lancaster University
Industrial Partner:
Worldwide Fruit

Sustainable Intensification of Top Fruit Production Through Precision Orchard Management Using Novel Remote Sensing Technologies

My research aimed to develop a method for sustainably intensifying apple production through the use of remote sensing systems. Improving disease management techniques enhances sustainability and reduce losses in apple production. My research focused on developing a sustainable apple production method using remote sensing systems to improve disease management, particularly targeting apple scab.

- Using high-resolution multispectral (near-infrared) imagery classified through deep learning convolutional neural networks (CNNs), I was able to identify apple scab infections as dark lesions on bright, healthy leaf tissue.
- Furthermore, the accuracy of the automated method was significantly higher, achieving 95% accuracy with NIR imagery compared to 90% with traditional methods.
- Another key finding was that prediction accuracy was influenced by the severity of infections, suggesting that localising imagery to smaller regions with fewer leaves was beneficial.
- Both the camera and classification models were low-cost and open-source, making them readily applicable to commercial orchards worldwide.

How were your findings relevant to food security challenges?

Early disease detection reduces reliance on fungicides, minimizing environmental harm while protecting apple yields. These findings address food security by promoting sustainable intensification, mitigating apple scab losses, and offering a scalable solution for managing diseases in high-value tree crops.

Chris Wyver

Based at:
University of Reading
Industrial Partner:
Worldwide Fruit

Quantifying and Mitigating Spatiotemporal Risks to Pollination Services Caused by Climate Change

I researched how fruit tree blossom timing and pollinator activity are being altered by climate change. I found that fruit tree blossom occurs earlier in warmer years, and in warmer locations, as does pollinator activity. However, these advances are not occurring at the same rate. This may lead to insufficient pollination within orchards, resulting in yield and quality deficits of fruit.

- Temporal asynchrony between fruit blossom and wild bee activity risks yield and quality deficits.
- Climate change enables wild pollinators to expand northward, shifting distribution of the crop pollination service, resulting in shifts in areas suitable for pollination dependent crop growth.
- We developed FruitWatch, a citizen science data collection system to track shifts in plant flower and fruit timing across the UK.

How were your findings relevant to food security challenges?

Pollinators are essential for many crops. Without these pollinators, yield, marketability and nutritional quality of orchard crops is under threat. Understanding their changing dynamics ensures resilient agricultural systems capable of adapting to climate change and safeguarding crop production.

Max Davis

Based at:
Lancaster University
Industrial Partner:
Worldwide Fruit

Improving Soil Health in Apple and Pear Orchards

Experiments from my project revealed minimal differences in soil health indicators between apple and pear orchards with and without wildflower strips. But, the story is more complex when we consider orchards in terms of farming intensity.

- A mesocosm trial demonstrated that the same wildflower species significantly enhanced soil processes, such as nitrogen cycling, when grown outside intensive orchard systems.
- These findings suggest that while wildflower strips offer ecological benefits, their impact on soil health in current intensive orchard management systems may be limited.
- This indicates that the potential for plant diversity to enhance soil health is context-dependent and not always directly applicable in heavily managed agricultural systems.

How were your findings relevant to food security challenges?

Increasing sustainability of production is at the forefront of the food industry. Understanding how plant diversity influences soil health helps inform agroecosystem management. New Environment Land Management schemes are targeting improvements in biodiversity in agroecosystems, such as wildflower strips. Understanding and developing knowledge of how these interventions can enhance ecosystem services and soil health is key to improving sustainability.

Laura Reeves

Based at:
University of Reading
Industrial Partner:
NIAB EMR and Worldwide Fruit

Pears, pests and natural enemies: modelling tri-trophic interactions in a changing climate

My research focused on pest management in pear orchards, with an emphasis on the pear psyllid (*Cacopsylla pyri*) and its natural enemies.

- I studied how temperature affects a predatory bug and demonstrated that future climate scenarios are unlikely to impact its effectiveness.
- I also found predation between two natural enemies of the pear psyllid (*Anthocoris nemoralis* and the European earwig (*Forficula auricularia*), but found they can still be used together for pear psyllid control without reducing predation efficacy.
- Pear flowering phenology has advanced due to climate change, with potential risks for pollination and pest management.
- Finally, a review highlighted the need for whole-ecosystem approaches to integrated pest management (IPM) of pear psyllid, considering climate-driven changes in trophic interactions.

How were your findings relevant to food security challenges?

The findings address sustainable pest management and climate adaptation in pear production, a globally important crop. Collectively, this work provides insights for optimizing IPM strategies in a changing climate, emphasizing the importance of natural enemies, phenological monitoring, and sustainable pest control practices. This minimizes environmental impacts and pesticide resistance while maintaining crop yields. The study on phenological shifts in pear flowering due to climate change highlights risks such as pollination mismatches and increased pest exposure, underscoring the need for proactive monitoring and adaptive management.

It is a bug eat bug world...

...and we should take advantage of that

Written by: Lucy Crowther

In recent decades, our agricultural system has grown increasingly reliant on chemicals for the control of insect crop pests. But what do we do when those controls start to fail us? And what happens when governments ban whole chemical groups due to their harmful effects on non-target species?

Farmers and growers cannot rely on spraying earlier, applying more, and swapping to the next chemical for much longer. Modern agricultural practices favour extensive monocultures and large open fields, leaving wildlife little room, but what if wildlife is the answer to common agricultural difficulties, and always has been.

For every insect that is the cause of these difficulties, there will be at least one other that is ready to eat it, lay eggs in it, or use it as a host to live on. In the past, when farms were smaller and grew a more diverse array of crops, farmers managed without chemical control, instead relying on these natural enemies of pests to keep populations under damage thresholds. With appropriate land management techniques, the farms of today can also rely on natural enemies as biological control agents.

Flower power

To promote natural enemies within farming landscapes, several techniques can be adopted. Natural enemies require insect prey in between pest outbreaks within the crop and many go through life stages that need an alternative source of food; pollen and nectar for adult parasitoid wasps and hoverflies. Providing these resources as well as shelter during periods of intense agricultural activities and hibernation will give a chance for natural enemy communities to increase, diversify, and maintain stable, and able to rapidly respond to pest outbreaks.

Floral field margins are one land management technique often implemented to provide habitat for wildlife, mainly pollinators and natural enemies. However, not all flowers are equally as good at providing resources to promote biological control. Caution must be taken, and more research conducted into which floral species specifically attract and support beneficial invertebrates and, on the other hand, which attract and support pest species.

Jessica Fostvedt Austin

Based at
University of Reading in collaboration with University of East Anglia
Industrial Partner
Greencell

Understanding the Epidemiology of Fungal Pathogens and Their Impact on Seasonal Variation in Avocado Quality Throughout the Supply Chain

My project primarily focused on the fungal species responsible for stem end rot of avocado. By screening hundreds of fruit from Mexico, Israel, and South Africa we determined a pattern of most abundant species of this disease. The next steps involved determining the pathogenicity of these species of interest, their associations with each other, and genetic characteristics.

- Identification of the most abundant fungal species responsible for the disease – White Striated (*Diaporthe* spp.).
- Exploration of pathogenicity, species interactions, and genetic characteristics to inform targeted control measures.

How were your findings relevant to food security challenges?

Avocados are one of the world's most lucrative fruit, post harvest disease can claim a significant portion of a farmer's crops. By reducing food waste, we will ensure a more efficient supply chain and increase our production without the additional pressure on our natural resources. Reducing food waste also mitigates global warming by decreasing the carbon footprint associated with wasteful food decomposition.

Keira Dymond

Based at
University of Reading
Industrial Partner
Greencell, Westfalia Fruit

Sustainable Avocado Production: Challenges, Solutions, and the Role of Biodiversity

I studied how insect pollinators are necessary for avocado pollination and production. My research explored the challenges of maintaining pollinator populations and the potential solutions to enhance their role in sustainable avocado farming.

- Field experiments in Chile showed that natural habitats play a vital role in supporting wild pollinator populations including wild bees and hoverflies.
- Pollinators richness and diversity was significantly higher in areas directly adjacent to natural habitat borders, compared to further inside in the orchard.
- Wild pollinators, especially flies and hoverflies, are key contributors to avocado pollination.
- A tool was developed to guide agricultural companies in quantifying their dependence on pollination and implementing pollinator protection strategies.

How were your findings relevant to food security challenges?

Avocados are a globally valuable and nutritious food source, so consistent production is vital for economic and nutritional security. The findings highlight the importance of preserving natural habitats within agricultural landscapes to maintain pollinator diversity and abundance, supporting ecosystem health. Additionally, the development of a pollinator protection tool equips agricultural stakeholders with strategies to safeguard pollinators, fostering more resilient and sustainable agricultural systems amidst rising global demand and environmental challenges.

Jamie Pike

Based at:
University of Warwick
Industrial Partner:
Primafruit

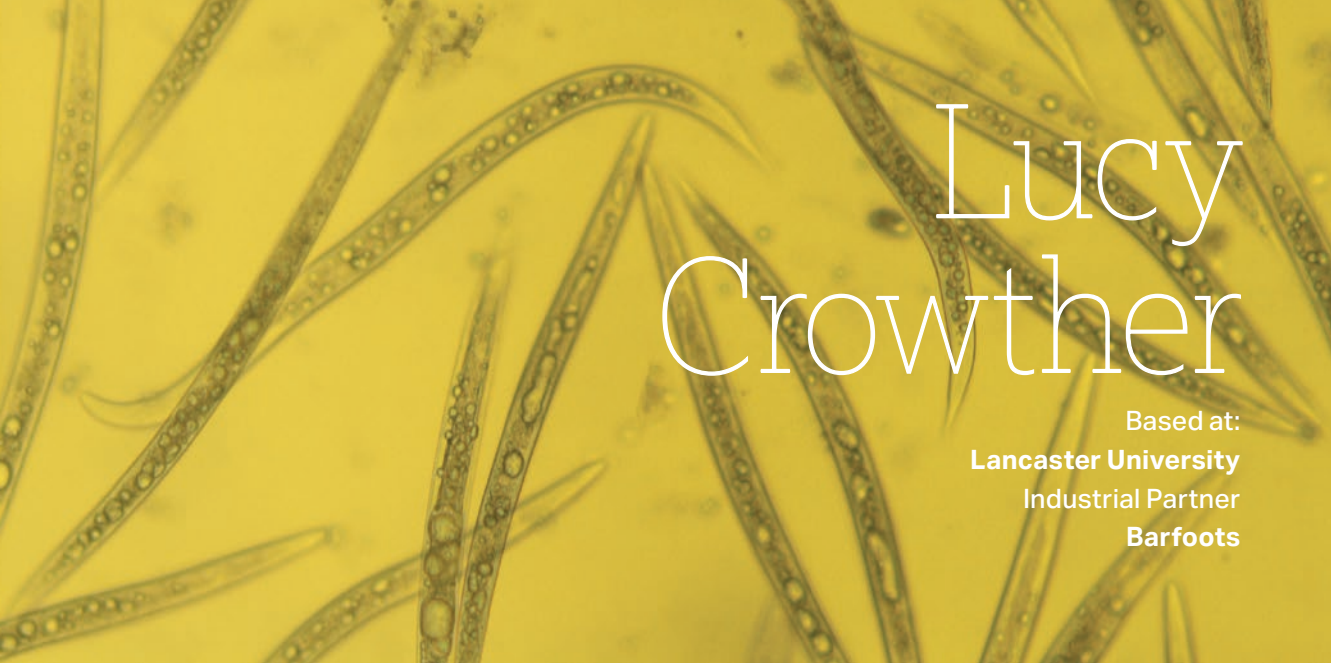
New Tools for Predicting the Spread of Fusarium Wilt in Bananas

I studied Fusarium wilt, a plant disease caused by species of the soil-borne fungus *Fusarium*. It affects a wide range of crops, including bananas, tomatoes and legumes, causing significant agricultural losses worldwide. My research uncovered unexpected diversity in *Fusarium* species affecting bananas, identifying one potentially novel species causing wilt like symptoms in banana in southern India.

- We developed a computational pipeline that discovered novel virulence genes across *Fusarium oxysporum* genomes, revealing host-specific virulence genes (effectors).
- We applied the first untargeted metabolomics study in banana and identified unique biomarkers that distinguish Fusarium wilt from other wilting stresses, supporting diagnostic development for disease management.

How were your findings relevant to food security challenges?

Bananas are a cash crop and vital global food source, particularly in India, China and some African countries. Thus, the emergence of new Fusarium pathogens are a significant food security concern. My computational pipeline enables ongoing diagnosis of Fusarium pathogens in bananas and other crops, aiding in tracking pathogen evolution and developing host-specific diagnostics. The biomarker-based approach provides a rapid and accurate diagnostic tool for agricultural services, ensuring timely interventions to protect banana production and support global food security.



Lucy Crowther

Based at:
Lancaster University
Industrial Partner
Barfoots

Integrating biological pest control techniques to enhance crop protection

My research highlights the overall effectiveness of floral field margins in support of the biological control of crop pests and identified which specific groupings of natural enemies of crop pests benefited from increased local vegetation diversity.

- My field research found that the entomopathogenic nematode species *Heterorhabditis bacteriophora* is an effective biological control option for the control of the serious brassica crop pest the swede midge (*Contarinia nasturtii*) and investigated effective application rates.
- The two other entomopathogenic nematodes that are widely commercially available, *Steinernema carpocapsae* and *S. feltiae*, were not an effective control of the swede midge in the field.
- All three entomopathogenic nematode species were unsuccessful at controlling in field populations of the cabbage root fly (*Delia radicum*).
- My thesis highlights the need for integrated pest management research to include the evaluation of interactive effects between the network of proposed methods. This will allow for such research to be more practical and informative to the progression and wide scale implementation of integrated pest management practices on farms.

How were your findings relevant to food security challenges?

My findings were directly related to crop pest control within the field, feeding into integrated pest management. This work identified successful non-chemical pest control methods, attempting to reduce crop yield loss, future-proof our food system, as chemical options are being lost due to resistance and regulations, and sustainable promote nature-based solutions within the farming industry.

Dion Garrett

Based at
Rothamsted Research & Warwick
Industrial Partner
G's Fresh

Using Landscape Genomics to Improve Management of Insect Pest Species

My research provided insights into the ecology and management of the aphid, *Nasonovia ribisnigri*, a major pest of lettuce crops.

- Despite a significant decline in the UK populations since 1965, linked to changes in agricultural practices and climate, *N. ribisnigri* remains a significant horticultural pest.
- Molecular techniques identified host plants in the aphid's diet, alluding to their preferred alternative summer hosts (green bridges).
- There was an evident East-West divide in the UK of *N. ribisnigri*, revealed through a population genetic analysis.
- A draft genome of *N. ribisnigri* was assembled, aiding in understanding pest management strategies and the identification of a possible candidate gene of host plant resistance.

Growers are advised to remove (or avoid sowing) specific host plants, such as chicory and crested dogs-tail, from field margins and monitor crop-edge infestations to break pest lifecycles and minimize crop damage. These targeted interventions are practical, scalable, and designed to enhance surveillance and management of *N. ribisnigri* populations, ensuring stable food production.

How were your findings relevant to food security challenges?

The findings support integrated pest management (IPM) practices that reduce reliance on chemical pesticides and promote biodiversity. These eco-friendly strategies enhance resilience against pests while supporting sustainable food production. Advances in genomic research pave the way for developing pest-resistant crops, ensuring stable lettuce production amidst climate challenges and evolving market demands.

Nicholas Kuht

Based at:
University of Warwick
Industrial Partner:
G's Fresh

Enhancing Salad Onion Yield and Quality Through an Understanding of In-Field Variability

My project identified early crop development as being a critical phase in which variability can be introduced into salad onion crops, potentially leading to reduced marketable yields.

- Early crop development is a critical phase for variability, affecting marketable yields.
- Soil texture and spatial variability significantly influence plant growth and performance.
- Controlled environment experiments indicated that seed size impacts seed vigour and early seedling establishment.

How were your findings relevant to food security challenges?

Crop uniformity underpins the marketable yields of many horticultural crops, including salad onions. Poor crop uniformity contributes to higher levels of in-field waste and reduces the proportion of plants falling within marketability criteria expected by retailers and consumers.

Reducing food waste across the food supply chain is an important aspect of sustainable food systems. This research sought to develop our understanding of crop variability and its causes, providing growers with possible opportunities to increase crop uniformity and performance, thereby improving economic returns and enhancing the sustainability of farm businesses.

Catherine Walsh

Based at:
Lancaster University
Industrial Partner:
Bakkavor

Optimising Yield and nutrient Consistency of Rocket Greens

My research focused on how farmers can exploit the C2 photosynthesis pathway to improve yield and nutrient consistency in the salad crop wild rocket (*Diplotaxis tenuifolia*). The pathway activates under hot, dry conditions conveying not only stress tolerance but also resilience to nutritional decline under increasing atmospheric CO_2 concentrations. This carbon metabolism shows great promise under climate change to maintain yields without changing soil inputs.

- C2 photosynthesis can recover CO_2 emitted by the plant itself, and use that for further photosynthesis.
- All tested cultivars of rocket have a strong C2 mechanism.
- Under predicted 2050 CO_2 levels, C2 species maintained their nutritional quality, unlike nutrient declines observed in C3 (wheat, barley, oats) and C4 crops (Maize, Sugarcane).
- C2 species exhibited excellent heat tolerance, offering climate resilience.

How were your findings relevant to food security challenges?

C2 photosynthesis optimizes productivity under hot, dry conditions, making wild rocket and other potential C2 crops valuable for climate-resilient agriculture. Developing or engineering C2 crops can secure future food systems under changing climatic conditions.

Anastasia Sokolidi

Based at:
Rothamsted Research & Warwick
Industrial Partner:
APS Group

Smart Detection of Airborne Diseases in Protected Crops

My PhD studied the smart detection of airborne diseases in protected crops, focusing on improving disease management in commercial tomato glasshouses.
The research made several key contributions to improving disease management in commercial tomato glasshouses:

- Tomato Powdery Mildew (*Erysiphe neolycopersici*) is a major disease of tomato crops, early detection of it is essential in its management
- We developed brand new molecular assays were for detecting Tomato Powdery Mildew before visible symptoms appeared, allowing for proactive management
- The use of spore traps and molecular diagnostics was effective in early disease detection within commercial glasshouses. This system enabled early detection of *E. neolycopersici* and Botrytis cinerea before visible symptoms on plants.
- Geostatistical modelling revealed that disease spread in glasshouses was influenced by worker pathways and other environmental factors. These insights inform targeted interventions to reduce disease transmission.

How were your findings relevant to food security challenges?
The findings are highly relevant to addressing food security challenges by offering sustainable and efficient solutions to disease management in tomato production. Early detection systems reduce the need for prophylactic fungicide applications, minimizing environmental impact while maintaining crop yields.
By enabling more precise and timely interventions, these tools help ensure a stable tomato supply, which is critical given the increasing demand and pressures on agricultural systems.

Patrick Skilleter

Based at:
Lancaster University
Industrial Partner:
Branston

Exploiting Genetic Diversity in Potato (*Solanum tuberosum*) to Overcome Soil Constraints to Tuber Yields

My project studied potato cultivar sensitivity to soil compaction under both laboratory and field experiments. Under modern mechanised agriculture, bigger farm equipment tends to put increased strain on soil structure, which is having negative impacts on crop production.

- Significant genetic diversity exists in potato genotypes' responses to compacted soil.
- We found high sensitivity in Charlotte, intermediate in Maris Piper, and low sensitivity in Pentland Dell cultivars.
- Sensitivity to ethylene, a plant hormone, was identified as a primary cause of root inhibition under soil compaction. We think compacted soil was trapping ethylene around the root, preventing root growth.
- Plant growth-promoting bacteria with ethylene-inhibiting enzymes restored root growth in sensitive genotypes.

How were your findings relevant to food security challenges?

By identifying the causes of yield gaps and providing methods to overcome them, crop yields can be improved. This helps overcome food security issues by increasing the area of land that can be used to grow crops, as land previously unsuitable for farming becomes viable, particularly in less developed areas where funds to resolve issues such as compaction are more limited.

Dominic Hill

Based at
University of Reading
Industrial Partner
Growing Kent & Medway

Improving phenotyping methods and irrigation efficiency in potato

I researched the development of a high-throughput phenotyping platform for the identification of drought-tolerance in potato. I studied the effects of pot size on the relationships between drought and yield in potato, and developing a drought-tolerant potato.

- A review highlighted traits like small canopies, open canopies, and dense shallow roots as important for potato drought tolerance, challenging the focus on root depth.
- Pot experiments confirmed small pots (5L) caused drought stress, with higher canopy temperatures and reduced yields, emphasizing the need for optimal pot sizes (20L).
- Canopy temperature varied predictably with water stress and cultivar tolerance, showing potential for real-time irrigation management and drought-tolerant cultivar screening.

How were your findings relevant to food security challenges?

Potato drought susceptibility is a critical issue with climate change threatening crop yields. By identifying traits that enhance drought tolerance, such as small canopies and dense shallow roots, the research offers pathways for breeding more resilient potato varieties. The study also improves irrigation management by using canopy temperature and leaf greenness as real-time indicators of water stress, helping optimize water use and reduce waste. These advancements contribute to sustainable agricultural practices, ensuring stable potato production despite environmental challenges.

Demonstration Farms

At the beginning of 2011, the Foresight Report on The Future of Food and Farming was published. It raised a number of challenges on sustainability, yields, population growth and world resources. Waitrose has had a long tradition of working collaboratively with suppliers and growers who share our values. Many of the issues raised in the report are not new to Waitrose having been articulated through the partnership with Lancaster University.

The Waitrose Agronomy Group represents the produce horticulture sector within our supply chain. Building on the data captured from The Waitrose Farm Risk Assessment, Waitrose created a number of demonstration farms in the UK and around the world, which showcase and disseminate the achievements of growers in relation to the sustainable crop production. Demonstration farms highlight areas of best practice in soil management, integrated crop management, water usage, biodiversity, energy usage on farms and reducing crop waste.

The primary objective is to demonstrate a step-change in a broad range of agricultural practices. There a number of unique farming challenges due to the diversity of the methods of production from glasshouse, root and surface field crops, uncovered and covered tree crops, bush crops and soft fruit. The principles of sustainable agriculture can be applied to all production types.

Nick Buck

Based at
University of Reading
Industrial Partner
Berry World

Integrating Control of a Major New Pest with Biocontrol and Pollination in Raspberries

Global raspberry production, a vital component of the soft fruit market, faces threats from a variety of insect pests, notably the invasive Spotted Wing Drosophila (*Drosophila suzukii*). This pest damages ripe fruit through oviposition or egg-laying, allowing prevalence for crop disease and reduces the marketability of the fruit. This pest poses a growing challenge due to an expanding geographical range as a result of climate change and increased pressure on farms due to pesticide restrictions.

- Crop edges and neighbouring woodlands are critical overwintering habitats for *Drosophila suzukii*.
- Insect exclusion mesh significantly reduces *D. suzukii* oviposition and emergence in fruit produced under polytunnels with minimal impacts on tunnel microclimates, natural enemy abundance in tunnels, and fruit quality, making it a valuable tool within Integrated Pest Management (IPM) strategies.
- Managed honeybees and bumblebees are the primary pollinators of raspberry flowers in polytunnels. Promoting pollination by a diversity of wild pollinators could improve pollination highlighting the need for strategies to optimize pollination by both managed and wild species.
- This thesis offers insights into pest and beneficial insect interactions in tunnel-grown raspberries in southern England, guiding farmers toward more sustainable and environmentally friendly IPM practices.
- By balancing pest control with pollinator and natural enemy conservation, these findings support the production of high-quality raspberries while promoting ecological sustainability.

How were your findings relevant to food security challenges?

Sustainable pest management strategies are urgently needed to control *D. suzukii* while protecting beneficial insects like natural enemies and pollinators. These findings support the use of mesh as a physical barrier to reduce *D. suzukii* oviposition and damage of tunnel-grown raspberries in the UK while having limited impacts on ecosystem services associated with soft fruit production.

By offering practical pest management solutions, my research supports sustainable raspberry production. Effective pest control reduces yield losses, ensuring a stable food supply while preserving ecological balance.

Miranda Burke

Based at:
Lancaster University
Industrial Partner:
Suncrop

Can We Reduce Food Waste in the Supply Chain from Farm to Fork?

Post-harvest spoilage is one of the biggest contributors to food waste globally. However, natural spoilage begins long before any visible symptoms are apparent. I studied non-destructive methods of identifying and sorting fruit and vegetables according to their rate of spoilage.

- Mid-infrared (MIR) spectroscopy identified spoilage biomarkers in fruit and vegetables before visible symptoms appeared.
- This system can be used to adjust storage conditions (i.e. temperature/humidity) to minimise the progress of food spoiling on the fly.
- Non-destructive MIR analysis can be used with chemometrics to successfully classify tomato fruit grown in different locations, providing opportunity for use to test for fraudulent produce in the supply chain using reference material.
- Near-infrared (NIR) spectroscopy performed less accurately than MIR.

How were your findings relevant to food security challenges?
These tools reduce food waste by enabling precise spoilage detection and improved supply chain management. Enhanced food distribution reduces environmental impact and ensures efficient resource use.

Sam Cusworth

Based at:
Lancaster University
Industrial Partner:
Waitrose

An Assessment of Plastic Use in Agriculture: Microplastics Pollution, Distribution, and Impacts in Agricultural Soils

I studied how agricultural plastics, specifically crop covers, (like polyethylene tunnels, greenhouse films, and row covers), while beneficial for improving crop yield and quality worldwide, directly contribute to microplastics pollution in agricultural soils.

- Plastic crop covers are integral for the promotion of agricultural productivity worldwide, but degrade during use and as a waste material, representing a significant contribution of microplastics to agricultural soils.
- Agricultural soils are receptors of microplastics pollution, even at sites without apparent plastic use or nearby pollution sources.
- Further experiments identified agricultural fertilizers as another significant source of microplastics, confirming that agricultural soils act as reservoirs for this pollution over time.
- Long-term experiments indicated that microplastics could have lasting negative impacts on soil health and crop productivity, highlighting their pervasiveness and persistent in agroecosystems.

How were your findings relevant to food security challenges?

These findings are highly relevant to food security. Agricultural soils are some of the most microplastic-contaminated environments globally. Emerging evidence suggests that microplastics pollution can directly and indirectly threaten the long-term productivity of agroecosystems, compounding the effect of global-change factors and soil degradation in these systems. To ensure sustainable food production, we must rethink the use, management, and disposal of plastics in agriculture, balancing the need for productivity with human and environmental health.

Jennifer Davies

Based at
Lancaster University
Industrial Partner
Produce World

Three keys to unlock legacy phosphorus for sustainable crop production: models, budgets, and expert elicitation

I investigated how managing legacy phosphorus (P) reserves in the soil can reduce the need for external P inputs, promoting both sustainable crop production and improved water quality. I found that effectively managing legacy P will require a suite of tools, including models, system budgets, and expert elicitation.

- Dynamic process-based models allow us to look into the future and explore how changes to management can influence the long-term cycling of P and give us an insight into things that can't easily be measured. Legacy P alone could sustain yields for more than 50 years on a cereal plot and around 150 years for a permanent grassland plot.
- System budgets can give farmers and land managers a better understanding of P use on their land, to identify hotspots of inefficiency, to understand whether P is accumulating or decreasing. I found that for a 1,600 ha organic estate, the P budget was largely in balance. Although this overall budget masked some inefficiencies between different enterprises on the estate.
- A questionnaire sent to UK farmers, land managers and advisers, explored the drivers and barriers to P management on farms and also highlighted the importance of a defining legacy P to influencing practices. Farmer's view of Legacy P is that it is "locked up" and inaccessible to crops. This could pose a challenge for encouraging sustainable P management practices and feeds into the insurance-based approach to P management.

How were your findings relevant to food security challenges?

The findings address food security by promoting the sustainable use of P, a vital nutrient for agricultural production. Global interest in legacy P is growing, not only as a threat to water quality, but also as a reserve that has the potential to offset fertiliser and manure P inputs in agricultural systems. By challenging the mindset that crops require annual inputs of P, improving nutrient use efficiency and tailoring strategies to farmers' needs, this research can support increased adoption of evidence-based P management strategies essential for long-term sustainable productivity.

Amanda Stoker

Based at
Rothamsted Research & Lancaster
Industrial Partner
Barfoots

The Impact of Agricultural Practices on Carbon Cycling in Soil

My research investigated the impact of agricultural practices on carbon cycling in soil over a three-year period, focusing on cover crops, glyphosate, and bio-inoculants. Key findings include.

- No single treatment or combination increased soil organic matter above pretreatment levels, suggesting artificial manipulation of soil carbon over time periods less than 3 years is not a feasible approach.
- Increased soil fungi were observed in untreated plots, plots with cover crops alone, and those with cover crops combined with glyphosate.
- Fungi, particularly mycorrhizae, showed potential for stabilizing carbon in soil.
- Cover crops treated with inoculants negatively impacted microbial activity and above-ground biomass.

How were your findings relevant to food security challenges?

A diverse microbial community in soil is essential for increasing soil carbon and supporting food production. Healthy soils foster plant growth and provide resilience against extreme weather caused by global warming. My findings emphasize a cautious approach to using chemical and biological solutions, advocating for a better understanding of their long-term impacts on soil microbial activity. Moreover, soil ecosystem services offer a potential carbon sink to help meet global net-zero carbon emission targets.

Edward Baker

Based at
University of Reading
Industrial Partner
G's Fresh

Developing Soil Health Indicators to Inform Land Management Decisions and Increase Crop Yield and Quality

My PhD explored sustainable agricultural practices focusing on soil health in lowland drained peatlands. Working with G's Fresh, we developed tools and frameworks to assess and manage soil conditions, particularly concerning the environmental and agricultural challenges posed by peatland degradation. Key contributions include the creation of the Peat Health Index (PHI) and the application of Bayesian networks to predict and interpret soil health metrics.

- Measurable indicators such as soil pH, cation exchange capacity, and organic matter to classify soil health.
- Strong correlations between the PHI, farmer perceptions, and key performance indicators like input use and crop yields.
- Evidence that healthier soils require fewer chemical inputs, reducing environmental harm while maintaining yields.

How were your findings relevant to food security challenges?

The project is highly relevant to food security as it provides practical solutions to maintain and enhance soil productivity in agricultural systems. By improving soil health, these tools mitigate risks posed by climate change and extreme weather on food systems, aligning agricultural practices with food security goals. The tools developed address soil degradation by providing metrics to enhance soil health and agricultural productivity. The focus on peatlands helps balance agricultural output with environmental conservation, ensuring long-term viability for farming communities.

Helena Ripley

Based at
Lancaster University
Industrial Partner
Primafruit

Maximising the effectiveness of soil erosion reducing cover crops through plant trait analysis

I studied plant traits to identify effective cover crops to reduce soil erosion in Spanish hillside orchards. This project was affected by Covid, so most of the experiments took place in Lancaster (in a greenhouse and polytunnel), although a field trial was set up in Cordoba and Spanish collaborators helped to collect data.

- Ten species, native to Spain and previously used as erosion-reducing cover crops, were assessed for above and below ground plant traits, infiltration and evapotranspiration.
- False broom (Brachypodium distachyon), Red broom (Bromus rubens), Alfalfa (Medicago sativa) and Bladder campion (Silene vulgaris) showed the most promise for erosion control.
- A survey and interviews showed how farmers receive information about management techniques. This revealed a disconnect between farmers and researchers, with even farmers interested in sustainable research unaware of what is happening in academic circles.

How were your findings relevant to food security challenges?

Soil erosion severely impacts food production, especially in the Mediterranean, where climate change exacerbates extreme weather. My findings provide farmers with actionable insights to select effective cover crops, ensuring soil sustainability and resilience for long-term agricultural productivity.

Ed Hill King

Based at:
Lancaster University
Industrial Partner:
Produce World Group

Novel Non-Destructive Detection of Internal Defects in Potatoes

Detecting post-harvest rot in potatoes without cutting them open has long been a priority for improving efficiency and reducing waste. My research explored the use of near-infrared (NIR) spectroscopy, a non-destructive technique, to identify internal defects within potatoes.

- Near-Infrared Spectroscopy can be used to train computer models for the detection of internal potato defects.
- Electrical sweep responses are also altered by internal tuber necrosis. These alterations create differential signals pre and post necrotic treatment, however the variance between tubers is too high for the reliable detection of internal tuber defects.
- Spectroscopy and electrical approaches, together with novel methods currently under investigation for extending the shelf-life of fresh produce, constitute new tools for reducing waste in supply chains.

How were your findings relevant to food security challenges?

Internal potato defect detection models could significantly reduce food waste by enabling non-destructive screening to preserve healthy tubers that might otherwise be discarded. This approach can extend shelf life, enhance transit durability, and reduce losses during distribution, retail, and storage. By addressing perishability and transit challenges, these advances could improve access to fresh produce in food deserts and reduce reliance on refrigeration, saving energy and supporting economies in regions with limited infrastructure.

How was being part of the Waitrose CTP important to your research?

"The program provided a network of academics, industry partners, and peers across institutions, fostering academic and personal growth. It offered a balance of training, conferences, and mental health-focused social events, which made the experience supportive and enjoyable." – **Miranda Burke**

"Collaborating with industry partners gave me real-world insights into agricultural practices, especially in areas like peatland management. The industry context grounded my research, making it relevant to pressing challenges like sustainability and food security." – **Edward Baker**

"Being able to perform research in an applied context was incredibly valuable. Having access to sites where wildflowers were already established increased the value of my research on plant diversity and soil function." – **Max Davis**

"The partnership connected me with my key industry collaborator, BerryWorld, and provided invaluable resources and insights into real-world agricultural challenges. This ensured my research was practically relevant and grounded in industry needs." – **Nick Buck**

"The CTP helped me land a Knowledge Transfer Partnership (KTP) position with the Earlham Institute and Tozer Seeds. It demonstrated my commitment to collaboration between industry and academia, which was crucial for my career advancement." – **Jamie Pike**

"The Waitrose CTP enabled me to run large-scale field trials, giving me access to commercial farms. The collaboration with industry partners, like Huntapac Produce, ensured the practical applicability of my findings." – **Hannah McGrath**

"Having the industry connections and experience was really helpful in gaining insights outside of academia. The team-building activities and supportive cohort environment enhanced the experience, fostering both personal and professional growth." – **Dion Garrett**

"The program offered invaluable training and events that helped me refine my research focus, make important industry connections, and address real-world agricultural concerns." – **Chris Wyver**

"Despite the challenges posed by the Covid-19 pandemic, the program's support through virtual events like writing retreats and symposiums helped me maintain my research momentum and build confidence." – **Alex Bleasdale**

"Being part of the CTP exposed me to a broad range of perspectives, not just within the food industry but across various academic disciplines. This enriched my research approach and broadened my understanding of agricultural systems." – **Alex Blomfield**

Hannah McGrath

Based at:
Rothamsted Research & Reading
Industrial Partner:
Huntapac

Bespoke Field Margins for Delivering Multiple Benefits to Fresh Produce

My thesis investigated the role of flower strips in commercial carrot production to enhance ecosystem services, particularly focusing on natural pest control, pollination and insect conservation. My work addresses the integration of conservation practices with practical farming needs, exploring economic and ecological implications. Key findings included.

- The composition of flower seed mixes significantly influenced insect communities.
- Mixes containing Phacelia and Cornflower attracted key flower-visiting insects, enhancing pollination and natural pest control.
- Increased net carrot yields were observed, especially at field edges, influenced by spray regimes and edge effects.

How were your findings relevant to food security challenges?
By demonstrating the scalability of implementing flower strips and their potential to minimize reliance on chemical pesticides, the research supports more sustainable agricultural practices that align with global food security and environmental sustainability goals. This contributes to sustainable and resilient food systems while maintaining stable crop production.

Konstantinos Tsiolis

Based at:
University of Reading &
NIAB East Malling
Industrial Partner:
Worldwide Fruit

The Missing Element of Sustainable Crop Pollination

My research expanded knowledge on nesting preferences of ground-nesting bees, which are critical crop pollinators. Recommendations were developed for creating and maintaining nesting habitats to support wild bee populations.

- Tailored management of bare ground and vegetated habitats can increase pollinator diversity and abundance in and around orchards, particularly ground-nesting bees.
- Bare ground habitats should include scraped topsoil and warm, well-drained soils with high stoniness content, and low vegetation cover. Vegetated habitats should be semi-shaded, and preferred soil conditions should be created for warm, low water-content soils with high stoniness content.
- Farmers should pre-survey potential locations for bee nesting habitats based on soil moisture and temperature preferences, ensuring close proximity to orchards for effective pollination.
- Nesting habitats should be marked clearly to prevent disturbance, with signs informing workers and the public about their significance.
- Additional flowering margins within foraging range of nesting sites should be provided to supply nectar and pollen beyond the orchard flowering season.

How were your findings relevant to food security challenges?

Understanding nesting needs of wild pollinators supports agri-environment schemes aimed at pollinator biodiversity conservation as well as contributing to more resilient crop pollination. This enables landowners and farm managers to create and maintain nesting habitats for wild bees and, with the provision of suitable food resources, contribute to the increase and diversification of bee populations.

The Waitrose Agronomy Group

The Waitrose Agronomy Group acts as a link between the Agri-science community and players in the UK food supply chain, communicating research requirements based on, among other things, the data from the Waitrose Farm Assessment.

Waitrose believes this is an accurate and powerful way of responding to growers' needs. In addition, novel research developments in the broad area of sustainable agriculture are communicated to the supply chain through the website and through Waitrose Innovation Conferences organised on a regular basis.

Conferences and our on-line dissemination infrastructure ensure that new research (our own and that undertaken by groups around the world) is given the best possible exposure within the supply chain. To deliver increased sustainability, neither the supply chain or the research community working in isolation can maximise impact and our approach to R and D is therefore designed to maximise interaction with all those who can have a positive impact in this area. The majority of our research is focussed under 'five pillars' defined by the Waitrose Agronomy Group Research Strategy:

- Soils
- Water
- Biodiversity
- Inputs
- Waste

The ultimate goal is to produce more good quality food, with the highest level of integrity and the lightest environmental farm footprint.

Alex Blomfield

Based at:
Lancaster University
Industrial Partner:
Butterfly Conservation

Dispersal and Population Persistence of a Threatened Butterfly in the Face of Habitat Fragmentation and Environmental Change

My research examined the population decline and dispersal of the pearl-bordered fritillary butterfly, a critically endangered species and bioindicator of environmental decline around agricultural land.

- Research on pearl-bordered fritillary butterflies showed that site isolation affects extinction risk and flight capacity, with climatic factors and nitrogen deposition also influencing abundance.
- Population synchrony was identified as an effective indicator of site connectivity and extinction risk, while mark-release-recapture studies assessed mobility.
- Morphometric analysis revealed that changes in wing size and thorax size are linked to reduced flight capacity in increasingly isolated populations.

How were your findings relevant to food security challenges?

Pearl-bordered fritillaries play a key role in supporting ecosystems that benefit agriculture by promoting biodiversity and ecosystem services. Their presence in well-managed habitats, like woodland edges and grasslands, aids pollinators, pest control species, and soil health. As a declining species under the UK Biodiversity Action Plan, their conservation is linked to agri-environment schemes, offering financial incentives for sustainable land management that benefits both biodiversity and agricultural resilience.

Plant-Pathogen Interactions:

How would plants survive amidst an epidemic?

Written by: Miranda Burke

The capability of humans to survive, adapt and potentially gain immunity to dangerous pathogens is a complicated issue shrouded by social and political intricacies.

Plants must encounter and defend against several types of pathogens, some more common than others, including bacteria, viruses, fungi, insects and nematode worms. All of these, humans and animals may also have to defend against. When faced with a potentially fatal pathogen, we humans rely on our immune systems as our defence. Plants also have an immune system, every cell in the plant can detect threats and form a response.

In 1951, Harold Henry Flor observed and described the relationship between plants and pathogens: for each resistance gene in the plant, there's a matching gene in the parasite: 'Gene for gene resistance' or gene triggered immunity. It was once thought to be a simple model, however it has since been shown that the plant immune system is far more complicated than this. The resistance genes work together in intricate networks. These networks enable the plant to act more effectively with a more robust detection and response system, even compensating for certain elements not working properly. The immune response is also able to adapt more easily to new pathogens, even whilst there is additional environmental pressure.

Plants and pathogens are in an evolutionary arms race, with an inevitable back and forth of adaptations which offer each side survival. When a pathogen attacks, plants can adapt to prevent or survive this attack. When the plants adapt, the pathogens adapt further. Some diseases including: *Pseudomonas syringae*, have developed an adaptation to release a toxin called coronatine which prevents the stomata closing, enabling the bacteria to enter and proceed

with infection. Some pathogens will excrete tissue damaging enzymes which surpass plants defences. The battle will continue.

The demand for plants is increasing as the global population exponentially grows. In crops global losses of yield to pests and pathogens are significant, for example; 22.5% of maize, 17.5% of potato, 30% of rice, 21.5% of wheat and 21.5% of soybean. In the past there have been epidemics that caused catastrophic damage. The Irish potato famine is a very famous example, *Phytophthora infestans* infected approximately half of the year's yield causing widespread famine.

It is now more important than ever that we develop our understanding of these mechanisms so we can further manipulate them for the benefit for agroecosystems and global food security.

Lancaster University