LOOKING TO THE FUTURE OF FARMING

ANNUAL REVIEW 2017 – 2018
Often in life, progress depends on successful evolution. At Rothamsted, we are always looking at how best the institute can evolve, particularly so at times of great change all around us, writes Achim Dobermann, the institute’s Director and Chief Executive.

And when better than 2018 to reflect on our evolutionary path, 175 years since Rothamsted’s inception. It’s been an extraordinary celebratory year of engagement. Highlights were our international scientific conference on long-term experiments, for which Rothamsted is renowned, and a fantastic “Festival of Ideas”, which was free and open to all.

**DIRECTOR’S FOREWORD**

**EVOLUTION, ENGAGEMENT, ENTREPRENEURSHIP**

“We’re trying to create a vibrant environment where people feel inspired”

**FILM #01: ANGELA KARP**
Geneticist; Director for Science Innovation, Engagement and Partnerships

Future Farming: Inspiring Innovation

Angela is introducing a “lean” approach to science at Rothamsted, where researchers engage early with those who will use their work, such as farmers, and test their riskiest assumptions.

“We’ve set up a new experiment, called the Large-Scale Rotation Experiment, comparing simple rotations with a greater diversity of crops, and ploughing versus not disturbing the soil at all”

**FILM #02: JONATHAN STORKEY**
Plant Ecologist; Leader, Achieving Sustainable Agricultural Systems

Future Farming: Return to Crop Rotation

In 1843, the founders of Rothamsted began testing different combinations of fertiliser on crops in fields to gauge the effects on yield; these tests became our famous Long-Term Experiments. Now we’ve started a new one.

For more, see our online Annual Review 2017–2018

www.rothamsted.ac.uk/AR1718
“Future farmers will be skilled with technology with access to knowledge. They will really know their farm and which parts of fields produce well. Crops will be selected that are good for those positions.”

For the conference, we welcomed nearly 200 delegates from 36 countries to our site. Conference sessions were followed by visits to the experiments and archives, and supper at Rothamsted Manor, the home of joint founder, John Bennet Lawes.

For the weekend Festival, we opened our doors to more than 8000 visitors keen to learn more about the science of feeding the world sustainably. We also created a 12-strong series of films on “Future Farming”, a thoughtful take from our scientists on where agriculture is heading (with online links from this review).

For this is our mission; we are focusing on solutions for improving the performance of agricultural systems through our new Science Strategy for 2017–22, now one year in. But the process of change never ends. Nor should it. In the past 12 to 18 months, the political environment has shifted worldwide. In the UK, as we ponder what the world could look like after a potential Brexit, Rothamsted has been actively engaged in discussion with those in Government who are thinking about the future of farming and in the wider world. In particular, science must accelerate growth in productivity so that farmers here in the UK are competitive in an increasingly challenging world market.

For Rothamsted, this means we must continuously ensure that our own research addresses the needs of others, namely the diverse clientele with whom we interact in the farming sector. And we must ensure that our research programmes are focused, and deliver tangible products, not just scientific publications. In short, Rothamsted must evolve to be more entrepreneurial.

“I’d like to see that what people are growing and what they’re consuming is good for them.”

So, how do we ensure that research results are not only excellent, but are also translated faster into practical applications? Well, this year, we secured a grant from the European Regional Development Fund to do just that, through our Agri-Tech Research Innovation Accelerator (AgRIA). We have formed a partnership with a number of universities, which bring a very different kind of expertise, namely the diverse clientele with whom we interact in the farming sector. And we must ensure that our research programmes are focused, and deliver tangible products, not just scientific publications. In short, Rothamsted must evolve to be more entrepreneurial.

“Laser technology will allow us to scan a whole field and tell the farmer: ‘in this place, you’ve got too many pests, but you’ve also got natural enemies and they will do the job for you’”

For more, see our online Annual Review 2017—18.

www.rothamsted.ac.uk/AR1718
We’re also working hard on giving people more space to think and take more risk in trying out new ideas, and on mechanisms that might help. For instance, we’re looking at seed funds and other support for scientists and students who want to work in a more entrepreneurial way. We want them to gain skills that enable them to be more mobile and more flexible in their research, perhaps via placements with industry or other partners.

As our researchers engage with the world beyond Rothamsted, that world also reflects on the work we do. Some of the technologies at the heart of our research are hotly debated in the public sphere. Most prominently, in recent times, have been controversial views about genetic modification and gene editing in crops, and discussion around pesticides and potential negative impacts on human health, the environment and biodiversity.

This year, we have continued to play a strong role in such discussions, as a voice for science that looks at facts and evidence as opposed to adopting a lobbying position for or against new technologies. It is important that we continue to play this role, in an independent and trusted manner. In the pesticides debate, for example, we play two roles. First, we conduct research that aims to find answers to the hotly-debated questions, though these are often complex. Second, together with partners including industry, Rothamsted is convinced that the future lies in bringing together genetic interventions with agronomical, agroecological and chemical approaches.

This is the goal of our strategic programme, Smart Crop Protection, funded by the government’s Industrial Strategy Challenge Fund, through UKRI. We believe it is not possible to achieve the sustainable future of agriculture that we desire in the foreseeable future to carry out highly productive agriculture without using chemicals at all. It’s a question of using those that are the safest, and in the safest way. Rothamsted can play a huge role here, and I hope that the debate can shift towards this more pragmatic ground. After all, we need to produce more food in the future, not less.

It is also important that, occasionally, we clearly state that we are in strong support of specific new technologies, because we believe not only that they are scientifically sound, but that they are also an important component of the variety of interventions needed to make agriculture more successful.

“Climate change, legislation, politics, public opinion, these are all part of this argument; it isn’t just the underpinning science. And as scientists we often don’t think of that”

Over this past year, we have taken steps to form new spin-out companies that are based on decades of excellent science at the institute. These spin-outs aim to commercialise Rothamsted’s scientific inventions directly...a path we need to take more often.

This year also saw the launch of an ambitious collaborative project to harness space technology and crop modelling to bring sustainable productivity increases to rice and oil palm farmers in Colombia by 2021. This new project, known as EcoProMIS (Ecological Production Management Information System), will combine earth observation data from satellites and drones with in-situ observations from smart sensors. It will deliver that information to hard-pressed farmers in near real-time and in a way that enables them to increase productivity and minimise the environmental footprints of their crops.

It is not necessarily the case that gene editing, for example, will lead to concrete commercial products, but it could, and I hope that more of our crop science innovations in the coming years will move towards commercialisation and wider use.

“The beauty of plants is that they are a green way of producing things, metaphorically and literally. There’s a real power in fusing synthetic biology, metabolic engineering and agriculture to do things in a more sustainable fashion”
The project links Rothamsted's expertise with that of UK-based SMEs and a variety of partners in Colombia in an exciting new field, via the UK Space Agency. I believe we can learn lessons from this project for applications in the UK as well.

Here, the Government's new Transforming Food Production Challenge clearly states a desire to make food production more productive, innovative, connected, resilient and sustainable by 2030. And the primary way of doing so is to make farming more precise by merging technology and information with an understanding of biological systems. If we can do it for rice and palm oil with EcoProMIS, why not for wheat in the UK, for which we already have a model?

Internationally, too, we have been developing other ambitious plans that make use of the latest digital and mobile technologies, notably through joint work with our partners at the China Agricultural University on the transformation of Chinese agriculture across an entire region.

And, in the UK, how to keep our soils healthy has been another strong theme this year. We've been working with farmers, they will not need to spray pesticides; so it's much less likely that they will, and this will be a more sustainable way to protect our crops.

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“The UK needs to define what it wants its agriculture to be like, to achieve its food security, nutrition, health and environmental goals”

In our 12-strong “Future Farming” film series, we challenged our senior scientists to explain the work they are doing and why it matters. We then asked them to imagine the future of farming in their specialist area. This showcase of their research and vision for the future featured across the weekend of the Festival of Ideas. The aim was to open up a dialogue with audiences, including the general public, farmers and policymakers.

The year has seen a flurry of scientific publications. Highlights include a landmark paper late last year from our team at North Wyke, showing that individual cattle can have a significantly different carbon footprint. This is exciting because it suggests, with careful breeding and feeding, a potential to reduce that footprint.

Early in 2018, our researchers isolated a natural resistance gene, called Stb6, to Septoria, which is Europe’s most economically damaging wheat disease and a fungal threat to wheat crops globally. What is so encouraging here is that this is the first successful unpicking of a wheat gene that confers resistance to this particular disease. Perhaps we can now find more such genes, en route to a natural barrier to infection, at a time when the fungus has already developed tolerance to most types of fungicides.

In campus news, this year saw the completion of our award-winning accommodation for visiting students and staff, the Fisher and De Ramsey Courts, named in honour of two of the institute’s most illustrious figures. Ronald Fisher was an outstanding statistician of the first half of the nineteenth century; John Fellowes, 4th Baron de Ramsey, is a farmer who was the Environment Agency’s first chair and a board member of both Rothamsted Research and the Lawes Agricultural Trust (LAT), which owns the campus site.

With our 175 year passing, we look forward to continuing to work with all those partners, new and continuing, with whom we have engaged, locally, regionally, nationally and internationally, as we rise to the challenges ahead in the science of feeding the world.

For more, see our online Annual Review 2017—2018

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Click here to watch all 12 films of the “Future Farming” series

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INSTITUTE STRATEGIC PROGRAMMES: TPM

TAILORING PLANT METABOLISM

Exploiting molecular processes to supply a wide diversity of high-value products

Our goal is to exploit fundamental understanding of plant metabolism to expand the value chains of crops; we are delivering novel and improved traits in two bespoke crops, Camelina and willow, through predictive re-programming of plant metabolism, writes Freddie Theodoulou, leader of the strategic programme, Tailoring Plant Metabolism.

Developing a new plant lipid fingerprinting platform and the use of lipid imaging approaches have allowed us gain new insights into the regulation of oil production in Camelina1,2. We now have a better understanding of how plant metabolism responds to manipulation by genetic modification (GM). We have identified new genes to enhance oil yield and have brought new lipid traits into the development pipeline. Thanks to the approval from the Department for Environment, Food and Rural Affairs (Defra) for a field trial (granted in May 2018), we are looking ahead to testing GM Camelina lines in real world conditions, in conjunction with the Camelina Flagship Project.

In willow, we have combined chemistry and genetics to discover genes involved in the biosynthesis of salicinoids, valuable compounds with potential medical and industrial applications. A comprehensive metabolomic screen of the National Willow Collection has been completed, facilitated by enhancements to our Nuclear Magnetic Resonance capability. Chemical profiles have been aligned with extensive genetic, transcriptomic and taxonomic data to provide a powerful, interactive discovery resource. Importantly, stability of lead compounds during ambient storage has been demonstrated, enabling progress in scaling up isolation procedures, to enable functional testing.1  Usher et al., 2017, Sci Rep 7: 6570, Tailoring seed oil composition in the real world: optimising omega-3 long chain polyunsaturated fatty acid accumulation in transgenic Camelina sativa. 2  Haslam et al., 2017, BBA Molecular and Cell Biology of Lipids 1862(8):782–785, Green light for lipid fingerprinting.

“What is your typical day at work?”
Typically, I spend half of my time on a computer analysing data and writing papers, and the other half in the lab performing experiments.

“How do you describe your work to a non-scientist friend?”
We discover and extract novel high-value products from willow plants that can be used in the pharmaceutical and industrial sectors.

“How do you describe your work to scientists in your field?”
Our work is focused on the isolation and characterisation of valuable novel compounds from willow, using spectroscopic techniques, such as NMR and mass spectrometry, with the aim of finding new natural products.

“Do you dream about science?”
In my dreams, the machines we have in the lab work beyond physical and chemical boundaries, and unthinkable findings are possible, more like in sci-fi movies.

“What part of your job excites you the most?”
The idea of being able to find some extraordinary way of helping society to overcome some problem, such as a disease, or even to create environmental solutions for the future.

“How often do you shout ‘Eureka!’?”
Not as often as I would like...and mostly when I am analysing my experimental data and I can finally find answers.

“Do you ever think ‘I should be doing something else?’”
This does cross my mind when things are not working as expected...after a good night’s sleep, everything is clear again.

“Is Science valued sufficiently highly by society at large?”
It is our duty as scientists to raise public awareness of Science; a greater understanding of its critical importance in every aspect of life can make society value Science.

“Why are you working in this field of science?”
Plants are fascinating. They avoid predators even though they cannot run. They adapt and survive extreme conditions. And they do most of it using chemical reactions that humans have difficulty copying in the lab.

“What makes a great scientist?”
Passion, critical thinking…and always looking for answers even while knowing there is no absolute truth.

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INSTITUTE STRATEGIC PROGRAMMES: DFW

DESIGNING FUTURE WHEAT

Delivering genes and traits for sustainable and resilient production

Wheat is one of the most important global crops, being grown on more land than any other commercial crop; it currently provides 20% of total calories consumed by humans daily worldwide, second only to rice. A 60% increase in demand is expected by 2050, as the global population increases towards 10 billion.

This programme aims to screen existing and new wheat germplasm for key traits, thereby identifying novel germplasm suitable for further exploitation. This germplasm, together with tools and information required for its exploitation, will be made freely available to the wider plant community in a readily accessible form.

The five-year programme to 2022 comprises a new collaboration of several UK organisations, namely Rothamsted Research, John Innes Centre, the Earlham Institute, NIAB, Institute of Food Research, the University of Bristol, the University of Nottingham and EMBL-EBI.

POURIA SADEGHI-TEHRAN
COMPUTER SCIENTIST

What is your typical day at work?
I work on the world’s first fully automated field phenotyping facility [a tall, mobile platform on rails that records images of growing plants 24/7]. My day-to-day job focuses on developing computer vision techniques to extract information from the overwhelming amount of plant data recorded by the platform.

How do you describe your work to scientists in your field?
I develop novel analytical paradigms to process high-throughput phenotyping data to help plant scientists to better understand the physiology and genetic diversity of crops.

What is the most important discovery (or revelation) yet to be made in your field?
Artificial intelligence is already a big phenomenon. It has started to transform every single industry, but human intelligence and AI are yet to be one tightly-coupled cognitive unit.

What drives or inspires your best work?
My family is always my source of inspiration. Their unconditional love and support have taught me so much about compromise and sacrifice.

How do you describe your work to non-scientists?
I make applications to build intelligent machines that tackle real-world problems.

Do you dream about science?
I always dream about things that I am passionate about!

Do you ever think “I should be doing something else”?
Never. From an early age I’ve always been deeply interested in maths, computers and programming languages. Making computers to understand and solve complex problems without human intervention is a great feeling.

Is Science valued sufficiently highly by society at large?
Science has always lifted the human spirit. I believe our modern society is open to novel concepts more than ever before, which encourages scientists to explore and discover more.
SMART CROP PROTECTION

Developing targeted and sustainable control of insect pests, weeds and diseases

Pests, pathogens and weeds destroy nearly a third of crops grown worldwide; this five-year programme aims to improve productivity by using the latest technology to detect, monitor, predict and control these threats. The work integrates chemical, genetic, biological, ecological, mathematical and agronomic approaches to deliver more targeted control strategies.

The aim is to deliver a new vision for managing crop health to limit the incidence, distribution, dispersal, evolutions and impact of crop biotic threats, and to maximise the efficacy and sustainability of control interventions.

Support for three years, to 2020, is coming from the government’s Industrial Strategy Challenge Fund.

Seven key principles define the strategy: pesticide-dominated crop protection strategies are prone to evolution of resistance; next-generation crop protection needs new tools and novel interventions; pests, weeds and pathogens will adapt to all interventions, and Smart Crop Protection is “evolution-smart”; a systems approach that integrates genetic, chemical, biological, ecological and agronomic interventions; more targeted delivery of crop protection using new technologies to provide a step-change in monitoring and surveillance; improved monitoring and surveillance will deliver evidence-based crop protection; Smart Crop Protection minimises trade-offs between production, sustainability and environmental objectives.

The programme has three main work packages. “Smart Surveillance” of pests, weeds and diseases; “Resisting Resistance” on the evolution of pesticide resistance; and “Next Generation Crop Protection” addresses the challenge of sustainable intensification of agricultural systems.

RAFAEL HOMEM
MOLECULAR BIOLOGIST

What is your typical day at work?
I start (and end) by selecting virgin flies. On an “injection day”, I spend a good few hours micro-injecting insect embryos; on a “cloning day”, I’m immersed in the lab; on a “bioassay day”, the flies meet insecticides; on a “computer day”, I analyse data, write and catch up with the literature; on a “hectic day”, I do a bit of everything.

How do you describe your work to a non-scientist friend?
I use the fruit fly to try to understand how insects become resistant to insecticides and why certain insecticides are more toxic than others to non-target insects, such as bees.

Do you dream about science?
Yes, especially after a challenging day at work.

Which part of your job excites you the most?
I really enjoy doing functional genomics. Being able to manipulate genes and genomes to try to answer a biological question is something that I find very exciting.

For more, see our online Annual Review 2017—2018
www.rothamsted.ac.uk/AR1718
ACHIEVING SUSTAINABLE AGRICULTURAL SYSTEMS

Securing food production while reducing farming’s environmental footprint

The post-war productivity gains of UK agriculture have been accompanied by negative unintended consequences for the environment, including dramatic declines in farmland biodiversity and the pollution of watercourses. At the same time, there’s an increasing gap between the potential of new crop cultivars and the yields achieved in farmers’ fields. This may partly be a consequence of a degraded natural environment and the “ecosystem services” that this environment provides to agriculture, including pollination and the regulation of crop pest populations.

The five-year ASSIST programme to 2022, supported by the BBSRC, will quantify the potential of these ecosystem services providers to improve the resilience of crop yields in the context of other constraints on productivity, including abiotic stress.

This will be done at a national scale across contrasting cropping systems, landscapes and soil types, combining expertise from crop scientists from Rothamsted, ecologists from the Centre for Ecology and Hydrology, and geologists from the British Geological Survey.

The programme will also explore opportunities for reducing the environmental footprint of agriculture while maintaining yields, so-called sustainable intensification.

What is your typical day at work?

There’s no typical day. It can vary from boiling in a glasshouse to shivering in a cold store; crunching numbers on the PC to crunching leaves in the lab; or, occasionally, I can be standing in a field of wheat gesticulating wildly to convey weed abundance measurements to other researchers.

How do you describe your work to a non-scientist friend?

I kill plants in new and interesting ways...so we can understand how to control weeds in crops more sustainably, and help to safeguard food security.

How often do you shout “Eureka!”?

Very rarely; for a start, my office-mate wouldn’t like it. Besides, the best discoveries often come when something hasn’t worked as expected, and so are preceded only by the noise of head-scratching and puzzlement.

Is Science valued sufficiently highly by society at large?

Not always. There’s a worrying mistrust of “experts”, with politicians and the media placing more emphasis on language and balance than on evidence. But scientific innovation surrounds us day-to-day. Its value is undeniable, and there will always be someone asking “How does this work...?”

What makes a great scientist?

Having the courage to try something new, go “off-protocol” and look at things in a different way. That won’t always work, sometimes spectacularly so, but the reward when it does will compensate. An ability to cope with long work hours, inconsistent funding and the infuriating comments of peer reviewers also helps.
We are aiming to identify the key processes that drive nutrient flows through farming systems so that we can intervene to achieve sustainable intensification of food production at the field, farm and landscape scales, writes Michael Lee, leader of the strategic programme, Soil to Nutrition.

At the field scale, for instance, we have combined X-ray computed tomography with metagenomics to study the effects of perennial and annual plants on the physical structure of soil. We also established a dry spectral laboratory and have begun to calibrate soils from both Europe and America for inorganic and organic fertilisers and for plant materials.

At the farm scale, we are developing metrics of sustainability for arable systems using data from long-term experiments in the UK and in Uruguay. To develop metrics for grassland systems, we are using data from North Wyke Farm Platform and from the international network, the Global Farm Platform.

At the landscape level, we are developing a Hierarchical Model Framework (HMF) to understand the fundamental mechanisms and processes that govern interactions between soils, plants and microbes, and thereby the gaps that can be filled with new experimental data.

Why are you working in this field of science?
I’ve always found animal behaviour fascinating, and I’d like to contribute to the understanding of domestic animals’ welfare; I’m also concerned about our responsibility as a species for preserving our planet and reducing our carbon footprint. Society and politics have a critical role in environment conservation, but science can lead to better practices and provide world changing discoveries.

What is your typical day at work?
I don’t have a typical day; I have times of computer work, soldering at the workshop, fitting data loggers on cattle or filming them at pasture... I can’t complain about having a boring job!

How do you describe your work to a non-scientist friend?
I study how cattle behave to have a better understanding of their impact on the environment, and how changing their behaviour could help to make livestock systems more sustainable.

How do you describe your work to scientists in your field?
I apply ethology and animal welfare science in beef cattle livestock using cutting-edge technology, with the aim of mitigating emissions of GHGs (greenhouse gases).

What is the most important discovery (or revelation) yet to be made in your field?
A deep understanding of animal communication (both intraspecific and human/animal) could provide us with useful information for management, welfare and productivity of livestock.

Do you dream about science?
I dream a lot about my research. During busy periods, I’m even working during my dreams.

What makes a great scientist?
A mix of creative mind, perseverance, concrete goals, passion about research... and luck.
Is Science valued sufficiently highly by society at large?
People benefit from the outcome of Science without fully realising it. Our work is extremely important for the progress of human society as a whole, which is not always sufficiently valued.

Why are you working in this field of science?
The progress of science requires more interdisciplinary knowledge, which is challenging and exciting.

What makes a great scientist?
Free thinking and integrity.

Is Science valued sufficiently highly by society at large?
People benefit from the outcome of Science without fully realising it. Our work is extremely important for the progress of human society as a whole, which is not always sufficiently valued.

What is the most important discovery (or revelation) yet to be made in your field?
Reliable detection and quantification of low abundance protein using mass spectrometry.

Do you dream about science?
YES.

Which part of your job excites you the most?
Advanced technology allows us to do things yet to be done, which can create more scientific questions.

Do you ever think "I should be doing something else"?
Our work is a learning process as we create new things, which generate a lot more opportunities to be doing "something else".

What drives or inspires your best work?
Desperation for something new… and thinking as a non-scientist.

What is your typical day at work?
Trying to meet the deadlines of different experiments, projects, collaborations, manuscripts, proposals et al (including this Q&A) at the same time…and trying to generate more opportunities to create such deadlines!

How do you describe your work to a non-scientist friend?
I’m studying changes in the abundance of plant proteins to solve agriculture-related problems.

How do you describe your work to scientists in your field?
Quantitative proteomics using Arabidopsis.

RISING TO THE CHALLENGES
Climate change, soil degradation, water shortage, fluctuating demand, accessibility of food, economic stability and inequity, loss of biodiversity...
The number and magnitude of risks facing agriculture are unprecedented, as is their interconnectedness and the rapidity with which the risk landscape is shifting. Finding solutions in isolation is no longer an option; we cannot optimise the agri-food system by tweaking its parts.

Rothamsted’s answer is to invest in new scientific, social and technological approaches that can address the whole system of risks simultaneously and seek synergistic interventions that deliver more from less and eliminate unintended consequences. We call it the Integrated Systems Lab, and the ISL Flagship is the project designed to translate those ideas into practice.

FROM ALGAE TO FIELD TO FISH TO HUMAN
The Omega-3 Flagship was established to translate the previous fundamental science discoveries by which genetically modified (GM) Camelina plants were engineered to produce omega-3 fish oils, writes Johnathan Napier, leader of the Omega-3 Camelina Development Flagship Project.

The ever-growing demand for these important nutrients cannot be met by oceanic sources and the goal of the Omega-3 Flagship is to help bring our plant-based source of fish oils to market and become a commercial product.

Since most of the fish oils that are harvested from the oceans is used in aquaculture (fish farming), we have focused on understanding and delivering to the needs of that sector.

HONGTAO ZHANG
PROTEOMICS SCIENTIST
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Rothamsted Research Annual Review 2017—2018
Grass may soon be greener with superfood for hungry cows

Tom Whipple, Science Editor
January 8 2018, 12:30am, The Times

A grass that is easier to digest could reduce the environmental impact of cattle

The problem with being a cow is you have to eat all the time just to stay alive. The problem with being a cow farmer is that you need a lot of land so that your cows can keep eating.

Scientists think they might have a solution to both issues, by engineering digestible grass, bioethanol power and GM crops that produce industrial products could be grown in Britain for first time

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Scientists think they might have a solution to both issues, by engineering digestible grass, bioethanol power and GM crops that produce industrial products could be grown in Britain for first time
For more, see our online Annual Review 2017–2018
www.rothamsted.ac.uk/AR1718
By the time our 175 year began in January, preparations for its first major highlight, an international conference at the site on "The Future of Long-Term Experiments in Agricultural Science", were already in full swing, writes Keith Goulding, Conference Chair and Rothamsted’s Sustainable Soils Research Fellow.

We welcomed over 170 scientists from 36 countries. The conference celebrated the achievements of LTEs, at Rothamsted and elsewhere, but looked principally to the future. It engaged a wide research community in the debate about sustainable agriculture and how LTEs can inform that debate. The presentations were recorded, and are available online, and there was much social media activity around the proceedings.

Delegates discussed ways to make better use of existing LTEs, the need for new LTEs and their relevance to farming in the future. They covered technologies for making the most of LTE data in line with FAIR (Findable, Accessible, Interoperable and Reusable) principles. Other issues included soil carbon, modelling, and the efficiency of the use of nitrogen in agriculture, led by the EU Nitrogen Expert Group.

During the conference, delegates visited Rothamsted’s own LTEs, which were started in 1843 on Barnfield and Broadbalk fields, and the archive of annual samples of grain, grass, fertiliser and soil, dating back to 1844, which they spawned. They were introduced to the electronic Rothamsted Archive (e-RA), our unique historical data repository, which is available online, free and open to all.

A principal aim of the conference was to determine the future direction of the Global Long-Term Experiments Network (GLTEN), initiated in 2017. Delegates agreed that it should be in the context of the UN Sustainable Development Goals and focus on three broad topics: reactive nitrogen, soil carbon and biodiversity.

Rothamsted was seen to have a key role in coordination and training in the experimental design and management of LTEs, especially in statistics.

Rothamsted acknowledges the conference sponsors: BASF, the UK Biotechnology and Biological Sciences Research Council, Fertilizers Europe, The International Fertilizer Association, The International Plant Nutrition Institute and The International Potash Institute.
175: TIMELINE

As part of the celebrations to mark our 175 year in 2018, we produced a vertical timeline of our most influential publications, nominated by staff and showcasing Rothamsted’s contributions to science and discovery across a diverse range of disciplines, writes Tim Wales, the institute’s Head of Library & Information Services, who co-ordinated the project.

The initial starting point was a call for highly cited publications of the past five decades but we quickly found that we were surpassing that target.

We had sought nominations from current and past staff, in part to harness the power of collective memory and also to ensure that influential works were not overlooked, especially those originating from the various independent institutes that have merged with Rothamsted over the years.

We received more than 130 nominations and indexed them in our Soutron library catalogue. This archiving system provides the underlying metadata for the timeline, which we designed to focus on papers within a decade, from the 1850s to the 2010s, and within a subject, from agroecology to statistics, via biotechnology and entomology to livestock and plant sciences.

There are 21 subjects at present but the number and range can broaden, as demand dictates. We have also included some departmental histories and obituaries of eminent scientists.

We welcome suggestions (library@rothamsted.ac.uk).

RECORD OF ACHIEVEMENT

JONAH PROUT
PhD STUDENT

What is your typical day at work? Data analysis from simulations and coding or measuring infrared spectra of soil samples.

How do you describe your work to a non-scientist friend? I’m creating a system to measure how much organic carbon (carbon from plants and animals) is in a soil, and to compare this finding with how much carbon the soil could hold.

How do you describe your work to scientists in your field? I’m using simulations to create indexes for soil organic carbon in England, Wales and Africa... as well as mid-infrared spectroscopy to measure soil properties for determining the index value of a site.

Do you dream about science? It depends how pressing a deadline is, otherwise science-fiction and flying.

How often do you shout “Eureka!”? Most days, followed by “Oh, wait…”

Which part of your job excites you the most? Learning new transferable skills in coding, and getting to grips with spectroscopy again.

Is Science valued sufficiently highly by society at large? With increasingly better science communication, the general awareness of problems, solutions and the value of research is improving, though a lot is still taken for granted.

Why are you working in this field of science? Soils are often overlooked despite being so important for life on Earth... and I like the good mix between desk, lab and field work.

What drives or inspires your best work? Trying to solve problems that greatly impact the environment and the public.

How do you describe your work to a non-scientist friend? I’m creating a system to measure how much organic carbon (carbon from plants and animals) is in a soil, and to compare this finding with how much carbon the soil could hold.

“‘I shout ‘Eureka!’ most days, followed by ‘Oh, wait…’”

We would also like to take this opportunity to thank our friends at Elsevier, Wiley and the Royal Society for working with LIS to enable free access to more than 400 of our publications for the duration of our anniversary year. This generous gesture is in recognition of Rothamsted’s contribution to the pursuit of scientific knowledge, and to our commitment to make as much of this knowledge as open and as free as possible.

For more, see our online Annual Review 2017—2018 www.rothamsted.ac.uk/AR1718
STARTED EARLY, STAYED LATE

Our anniversary year began early, well before 1 January 2018, after we decided to stage a celebratory Festival of Ideas, free and open to all…and it was worth it!

With eight months of planning and preparation, and the engagement of the majority of staff across our two campuses, we marked the start of formal experiments on site in 1843 with a celebration of today’s science here, science that looks to the future of sustainable food production.

We had not done anything like this before, not on the same scale. More than 40 groups of staff devised and revised ways of presenting their work to engage the most diverse of audiences, from knowledgeable stakeholders and technical collaborators to interested adults and inquiring children.

In the end, there were 35 exhibits across ten zones: Gene, Global, Health, Heritage, Wheat, Soil, Tech, Experiment, Grassland and Insect. Each offered well-crafted posters to help explain what was going on, and many incorporated bespoke accessories, such as the “Tree of Trade-offs.”

There were six tours: taking in the National Willow Collection; viewing the inside of the glasshouses and controlled environments; magnifying to grand scales in the BioImaging Lab; sleuthing in the Library; strolling through Manor Gardens; and riding around the farm on a tractor-trailer.

“The best bit for me was when I walked past a young boy who said to his dad: ‘Dad, I’m having such a good day’”

“Wow! Wow! Wow! What a day…it is no surprise you are world leaders”
“It’s very motivating as an early career scientist to see the public, especially children, getting so excited about science”

And there were two displays: one promoted our multi-talented and multi-cultural team, and the other showed off our heavyweight farm machinery of tractors and sprayers, foragers and harvesters, drillers and cultivators.

A series of 12 films on “Future Farming” was also commissioned to explore the broad range of Rothamsted’s expertise, with senior scientists describing the work that their teams are doing and why it matters. They also

More than 8000 people came onto the site over three days: the first day, a preview on the Friday, was dedicated to local schoolchildren (from Luton and Harpenden) and to our stakeholders; the weekend was open to everyone...and the weather did not let us down.

Feedback from visitors and staff has been universally positive, as the Festival’s Evaluation Report shows. It highlights the tangible demand for knowledge about science, communicated in engaging and attractive ways, just as the staff of Rothamsted did over that wonderful weekend in June. 

“IT’S MORE HANDS ON, MORE INTERESTING AND MORE CURRENTLY RELEVANT THAN A TRIP TO THE SCIENCE MUSEUM”
Collaborations with industry are critical to our ability to deliver innovations from our science as improved practices, products and technologies

Although industrial collaborations constitute a small proportion of the work we do, typically 10% of our annual budget, they are an important means of ensuring that our science delivers environmental and economic benefits to society, writes Bianca Forte, Rothamsted’s Alliance Manager for Knowledge Exchange & Commercialisation.

And what a great year 2017–18 was for industry collaborations at Rothamsted Research. The projects running under our Framework Agreement on wheat innovation with Syngenta, now almost close to their end, continued to yield excellent outputs.

One area of work that is attracting great attention from the global academic community is the development of a new viral vector system to express proteins in plants. This new tool for studying the function of genes will be particularly useful in plant species, such as wheat and maize, for which transformation-based methods are unavailable or are too time- and labour-demanding. “This should allow a major leap forward in scientific knowledge across a whole range of crops,” says Dave Hughes, Global Head of Technology Identification and Evaluation for Crop Protection at Syngenta.

Our collaborations under the Framework Agreement on smart crop protection with Bayer continued to grow, with two new projects signed off last year. Through a multi-disciplinary project, we are bringing together our scientific knowledge of insect behavioural ecology, pest management, FaunaPhotonics’ optics, engineering and data science capabilities and Bayer’s expertise on digital platforms for monitoring and decision support services.

The aim is to develop new in-field sensors to monitor pests and beneficial insects automatically. This technology has the potential to help farmers reduce pesticide use and we are now at a stage where we will start sharing results at scientific and industry conferences.

Through our Framework Agreement with Alltech, we are not only investigating novel applications for solutions in crop and forage production, but also fostering the next generation of scientists. Last year, Achilles Christou, our joint PhD student, won a President’s Prize for a highly commended presentation at the annual conference of the British Society of Animal Science. Achilles is investigating how nutritional amendments, derived from microbial fermentation, can improve forage quality and crop productivity in maize and ryegrass.

“Without highly-trained talent that has the commercial awareness and multi-disciplinary skills to challenge how we view traditional management practices, the industry would stand still,” says Mark Gaffney, Research Project Manager at Alltech, and co-supervisor for the project.

Finally, recognising the challenges that new tech-based companies face in the initial phases of product development, we also invested considerable effort last year into raising funds to improve our ability to collaborate with start-ups and small- and medium-sized enterprises (SMEs). We could not be more pleased with the results.

We are now a partner in two programmes, funded by the European Regional Development Fund (ERDF), that will enable start-ups and SMEs to engage in innovation projects. We also laid the groundwork for soil phosphorous; with Glas Data, we are developing an app for yield prediction and nutrient management; and, with Precision Grazing Ltd, we are studying the benefits of cell grazing.

The £6.4M ERDF-funded Environmental Futures and Big Data Impact Lab is giving Devon-based SMEs an opportunity to access our expertise in soil, water, plants, livestock, environmental sciences, data science and machine learning.

Last year, we launched a project with Elemental Digest Systems, a local SME that has developed a process to convert abattoir waste into a novel micronutrient-rich phosphate fertiliser. We are helping them to develop application rate recommendations for different crops and soil types.

With all these partnerships and programmes now in place, we look forward to the joint work that we will do with industry in the next few years to come. We look forward to helping these businesses, and many others, to develop more effective and sustainable solutions for British farmers.

Perhaps later, we can even help them to adapt and take the best of British technologies to international markets.

For more, see our online Annual Review 2017—2018

www.rothamsted.ac.uk/AR1718

1 Bouton et al., 2018, Plant Physiol 177: 1352–1367, Foxtail mosaic virus: A new viral vector for heterologous protein expression in wheat and maize
We have begun one of the most ambitious programmes to provide lasting improvements in nutrition in sub-Saharan Africa, bringing our soil and crop expertise to bear on the falling levels of essential nutrients in diets around the world, writes Steve McGrath, a specialist in the bioavailability of nutrients and head of the Sustainable Agricultural Sciences Department at Harpenden.

Rothamsted is part of a diverse multinational team of experts from agriculture to ethics that is working on a 43-month programme (from January 2018), known as GeoNutrition and funded with a grant of £4.4 million from the Bill & Melinda Gates Foundation.

The programme is focusing on deficiencies in selenium and zinc, which impair growth, inhibit cognitive development, and suppress the immune system. Its experts, from Ethiopia, Malawi, Kenya and the UK, aim to map cropland, test the efficacy of micronutrient-enriched fertilisers, assess public health policies and strengthen training networks.

In Ethiopia, there are Addis Ababa University, the International Maize and Wheat Improvement Centre (CIMMYT) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT); in Malawi, Lilongwe University of Agriculture & Natural Resources (LUANAR); in Kenya, CIMMYT again and the World Agroforestry Centre (ICRAF); and, in the UK, Rothamsted, the British Geological Survey (BGS), the London School of Hygiene and Tropical Medicine (LSHTM) and the University of Nottingham, which is leading the programme.

“We want to gain a better understanding of the multiple factors that influence the transfer of nutrients from soil to crops to diets”

Balem Melesse, left, and Wubie Mesfin, from the South Gondar Zone agricultural office in Ethiopia, prepare to sample soil and wheat in the Amhara Region of Ethiopia.

Edward Joy/LSHTM

For more, see our online Annual Review 2017—2018

www.rothamsted.ac.uk/AR1718
We are leading a major collaboration project in South America to harness space technology, in the form of earth observation data from satellites and drones, and bring sustainable productivity to rice and oil palm farmers in Colombia.

Fewer than one in ten of Colombian farmers have access to technical assistance to manage their land more efficiently. The new project, known as EcoProMIS (Ecological Production Management Information System), is designed to create a commercially viable solution for sustainable agriculture by April 2021; a solution that is free to farmers and funded by industrial stakeholders.

EcoProMIS aims to combine space data with in-situ observations from smart sensors and to deliver that information to farmers in near real-time and in a way that enables them to increase productivity and minimise the environmental footprints of their oil palm and rice crops.

Rothamsted signed the 38-month, £3.9M contract with UK Space Agency in February, and then appointed Agricompas, a data analytics company based in the UK, to jointly forge and manage a public-private partnership, which was established in mid-May.

Rothamsted’s partners also include, from the UK, Elastacloud, for data science, and Pixalytics, for satellite earth observation; from Colombia, the International Centre for Tropical Agriculture (CIAT), Cenipalma and Fedearroz, for local agricultural knowledge; and Solidaridad, the international organisation behind the Fair Trade movement, for socio-economic expertise.

“Smart technology can deliver timely data to farmers to increase their productivity and minimise their environmental footprints”
Rothamsted International (RI) is about advancing scientific understanding in low-to-middle income countries for long-term and sustainable solutions to emerging and persistent challenges in food production, writes Simon Vaughan, Head of Grants and International Programmes.

Its primary activity is the RI Fellowship Scheme for the early career development of agricultural researchers. RI fellows use state-of-the-art facilities at Rothamsted where exceptional networking opportunities often form the basis of long-term international partnerships.

In 2018, RI celebrates its 25th anniversary with ambitious plans to increase the number of fellowships and to expand its in-country support for RI fellows following their return home. We also expect to announce a new joint scheme with the University of Nottingham’s Future Food Beacon Programme.

Founded by the Lawes Agricultural Trust as a not-for-profit initiative, RI is supported by donations from the public, trusts and foundations. All funds directly support training in agricultural research, research that positively impacts the livelihoods of people living in some of the most impoverished and environmentally challenged regions of the globe.

Further information on these activities and the application process can be found at www.rothamsted.ac.uk/RI

For more, see our online Annual Review 2017—2018: www.rothamsted.ac.uk/AR1718

What is your typical day at work? It depends on the time of year but includes work in the laboratory or in the fields and, of course, work in the office analysing data or just studying….different tasks, not routine.

How do you describe your work to a non-scientist friend? We’re aiming to better understand the factors that affect wheat development and productivity; our goal is higher yields and improved quality.

“Great scientists should be able to communicate their work effectively…and not focus only on their own field”

How do you describe your work to scientists in your field? We focus on how plant nutrition and applied chemicals affect wheat development, by analysing the expression of genes to understand their regulation, and by combining results from both field and hydroponic experiments.

Which part of your job excites you the most? The part that challenges me the most. This is the interpretation of my results and my findings. I believe this is the real challenge for every scientist.

Do you ever think “I should be doing something else”? Not so far. In fact, I can’t imagine myself doing anything else. I enjoy my work…and this is satisfactory proof that I have made the right choice.

Is Science valued sufficiently highly by society at large? Yes, it is. Most people, at least in Greece, appreciate Science and its contribution to society. There are always some others who argue the opposite, that it is a waste of money.

What drives or inspires your best work? My curiosity about plants’ abilities inspires me most…and studying something applied, which might be useful in the future.

What makes a great scientist? Apart from technical skills, they should be able to communicate their work effectively to the public. What is more, a good scientist should not focus only on their own field but gather expertise in other areas, too.
ON A MISSION TO SECURE FOOD

From fruit and veg to AI and data science, the high life for postgrads never ends

Rothamsted’s vibrant student community continues to grow, thanks to a diverse portfolio of PhD opportunities with a variety of university and industrial partners, writes Freddie Theodoulou, chair of the institute’s Postgraduate Education Committee.

Our existing Doctoral Training Partnerships, the Nottingham-Rothamsted DTP and the SWBio DTP, continue to provide excellent collaborative PhD projects in the BBSRC priority areas, “Agriculture and Food Security” and “Industrial Biotechnology and Bioenergy”. Projects with an environmental focus are supported through the NERC Envision DTP and the Lancaster Joint Graduate School for the Environment; and specialist postgraduate training in soil science is delivered through BBSRC and NERC’s STARS Centre for Doctoral Training (CDT). As the partnerships mature, Rothamsted is looking to continue and extend these successful alliances in the new round of DTPs and CDTs from UK Research and Innovation (UKRI).

October 2017 saw the first students arrive for three new training programmes. The BBSRC Waitrose Collaborative Training Partnership (CTP) offers doctoral training in sustainable crop production, sustainable soil and water, and biodiversity and ecosystem services in agriculture, with a focus on fruit and vegetable crops. Students are registered at one of three partner universities (Lancaster, Reading and Warwick) and all have an industrial supervisor from the Waitrose Agronomy Group. Our homegrown Agricultural Research and Innovation Accelerator (AgRIA) now hosts five PhD students, registered at Cranfield University and working on soil science projects with a strong entrepreneurial component. We also launched four Rothamsted-Reading Alliance studentships to explore nutrition and informatics along the entire food chain.

In 2017, student numbers were boosted by projects supported by the National Productivity Investment Fund. Themes for 2018 are AI and data science, which will also feature in the new round of DTPs and CTPs. Two new collaborative training ventures are set to launch in the coming year. Four multidisciplinary Farming Futures PhD projects will form part of the Rothamsted-University of Bristol Strategic Alliance; and we are looking forward to welcoming the first cohort of five Nottingham-Rothamsted Future Food Beacon students in October 2018. Jointly funded through the University of Nottingham and the Lawes Agricultural Trust, these studentships address international agricultural development and are open to candidates of all nationalities.

With such a diverse group of partners and projects, Rothamsted is a stimulating place for postgraduate education where cohesion and interactions among our student community are fostered. The highlight of the year was the annual Student Symposium, which brought together the whole student cohort to socialise and share research across the spectrum of Rothamsted’s science portfolio. Postgraduates also had the chance to join boot camps in public speaking, storytelling and communicating, “Speaking Science 101”, in which they could learn about presenting their own research to the general public. These practical sessions led to performances of three-minute flash talks in the “Talk Tent” at Rothamsted’s Festival of Ideas and at the Herts County Show, plus engagement opportunities at other public events.

“For postgraduates who want to develop their presentation skills and then get to perform in front of a live audience, this is a great opportunity.”
We launched into more regular film making and production this year, taking out our video cameras at seminars, conferences, one-off events or even to interview researchers on the publication of their latest papers. We used film alongside still images and text to record and promote the occasions.

The aim is not only to enhance records of presentations to make them more widely available and accessible, but also to help to make it routine for scientists to be talking on camera about their research and about the longer-term implications of their work. Familiarity breeds consent.

For the Rothamsted Seminar Series, we streamed the talks live (with speakers’ consents) and also recorded short, four-to-five minute interviews. We linked both films (on our YouTube site) to an accompanying online news story about the presentation.

Among our invited speakers were Ottoline Leyser, Director of the Sainsbury Laboratory Cambridge University (SLCU), who explained her awe for the plasticity of plants, and Paul Nurse, Director of the Francis Crick Institute, who spoke of how and why agriculture and biotechnology had become the poor cousins of research investment in the life sciences.

Internal seminar speakers included Lin Field, Head of Bionteractions and Crop Protection, with her wry “Neonicotinoids and bees – what’s all the fuss been about?”, and Nigel Halford, plant geneticist and a specialist in metabolic regulation, with his darkly humorous talk about the food toxin, acrylamide, “Have we had our chips (not to mention our toast, biscuits, breakfast cereals, crisps and coffee?)”?

Other highlights were Gia Aradottir’s trip to participate in the Royal Institution Christmas Lectures, with her aphids and parasitic wasps; our annual Postgraduate Student Symposium; the first visit by our new local MP, Bim Afolami; and a taste of the 15th annual stakeholders’ meeting of the Wheat Genetic Improvement Network (WGIN), which secured funding to 2023 in February.

Among the researchers prepared to trial the idea of short video clips on Twitter to promote their latest research papers were Rowan Mitchell, on less chewy grass; Matthew Paul, on boosting cereal yields; Paul Neve, on the curse of black-grass; and Robbie Manning-Smith, on fungal sex.
Rothamsted Research brings together talented people from all over the globe to support work in a range of disciplines that aim to find more sustainable ways of feeding the world’s growing population with more nutritious food.

Here are our staff, students and board members at January 2018, compiled by the institute’s Human Resources Department. The Lawes Agricultural Trust (LAT) provides land, facilities and funding; the Biotechnology and Biological Sciences Research Council (BBSRC) provides strategic funding; and Rothamsted, LAT and BBSRC are shareholders of the Rothamsted Centre for Research and Enterprise (RoCRE), an incubation space for new businesses, from inside and outside the institute.

**OUR PEOPLE**

**EXPERTISE AND ENTERPRISE**

**Expanding Horizons**

**Matt Ashfield**

**Matt Ashfield**

**Vasthi Abadie**

**shareholders of the Rothamsted Centre Department. The Lawes Agricultural ways of feeding the world’s growing**

**talented people from all over the globe**

**OUR PEOPLE**

**Aimeric Martin**

**Bayon**

**Dungait**

**Angela Doherty**

**Diez de la Fuente**

**Caterina Davies**

**Clare Crook**

**Laura Clark**

**Suzanne Charteris**

**Kettles**

**Cerezo Medina**

**Caulfield**

**Alison**

**Laura Melanie**

**Stephan Cara**

**Griffith**

**Andy**

**Kate Glendining**

**Martin Gandini**

**Freeman**

**Franklin Julian**

**Durenkamp**

**Imogen**

**Macdonald**

**Macalpine**

**Alison**

**Nadine Lim**

**Lee Michael**

**Kate**

**Rebecca Kettles**

**Joynes**

**John Homem**

**Headon**

**Richard**

**Mitchell**

**Rowan Milne**

**Helen Mead**

**Andrew Mackay**

**Mackay**

**Operations (% Female) Operations (% Male)**

**Zhang**

**Wilkinson**

**Andy**

**Richard**

**Benjamin**

**Simon**

**Verena Perryman**

**Suzanne Parmar**

**Linda Clarice Paul Young**

**Mitchell**

**Rowan**

**Helen**

**Andrew**

**Mackay**

**Richmond**

**Kerridge**

**Lukas**

**Evan**

**Carlton**

**Bennett**

**David Boulton**

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