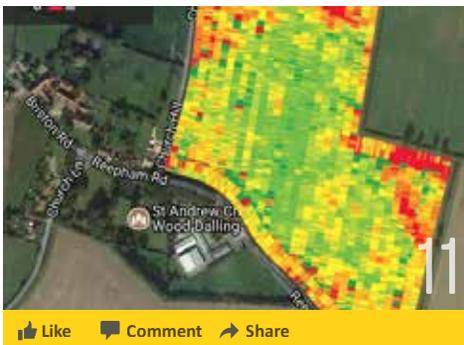


YEARBOOK 2019



ROTHAMSTED
RESEARCH



About Rothamsted

Rothamsted Research is the longest-running agricultural research institute in the world. Through independent science and innovation, we make significant contributions to improving agri-food systems in the UK and internationally. In terms of our economic contribution, the cumulative impact of our work in the UK exceeds £3 billion a year. Our strength lies in our systems approach, which combines science and strategic research, interdisciplinary teams and partnerships. Rothamsted is also home to three National Capabilities: The Long-Term Experiments, Rothamsted Insect Survey and the North Wyke Farm Platform.



**Biotechnology and
Biological Sciences
Research Council**

We are strategically funded by the Biotechnology and Biological Sciences Research Council (BBSRC), part of UK Research and Innovation, a non-departmental public body funded by a grant-in-aid from the UK government.

With additional support from other national and international funding streams, and from industry. We are also supported by the Lawes Agricultural Trust (LAT).

FOOD. FUTURE PROOFED.



With populations booming, resources dwindling and habitats degrading, we urgently need to feed more people using less land with the least harm to the planet.

When done badly, it can cause serious harm – but how we grow, make and consume our food has huge potential for win-wins. And science holds the key to unlocking those.

Our multi-pronged approach aims to improve the foods we grow and rear, and the way we farm them. From next-gen crops to improving soil health, from the running of complex climate simulations to long-term, farm-scale monitoring, we're helping make food more nutritious, more enduring, and more disease resistant.

Our vision is for a world where hunger and malnutrition are a distant memory, where food is grown in harmony with the natural world, and where the farmers who grow our food and manage our land, can make a fair living.

IT'S COMPLICATED



“Our house is on fire”

And with what fast became the rallying cry for a generation, the overriding narrative for 2019 (and beyond) was set.

The year had barely begun when [Greta Thunberg scolded the delegates in Davos](#), whilst in Oslo the [high-profile launch](#) of the *EAT-Lancet Commission on Food, Planet, Health* established the tone for a year where consumers were implored to go vegan and farmers came under attack from seemingly all quarters. Plant-based diets became the fashion, as sustainability arguments even broke out over the [vegan credentials of avocados and almonds](#).

As with any media driven debate, the nuances were often lost and the discussion too narrowly focused. But with grazing land already covering more than a quarter of the globe, and human health, livelihoods, and perhaps the entire biosphere, at stake, the world cannot afford to get this wrong. With an experimental farm set up to examine the very issue of more sustainable livestock production, our ‘farm lab’ research at North Wyke took on even greater prominence – and urgency – in 2019 (see July for more about that).

And whilst enormous beef feedlots and widespread deforestation are clearly damaging to the environment, there is a debate to be

had in many countries on the role of pasture fed livestock in either worsening or mitigating climate change. That was made clear when the journal *Global Change Biology* announced its annual ‘most downloaded’ list in January, and a [Rothamsted paper on limitations to increasing soil carbon](#) was second (and was only beaten to first place by a paper on 2018’s environmental cause celebre, microplastics).

The results showed that the “4 per 1000” target for increases in soil carbon launched at the United Nations Framework Convention on Climate Change in Paris in 2015 can be achieved in some cases – but usually only with measures that would often be impractical or unacceptable to farmers.

If nothing else, this demonstrates the meteoric rise of the subject of climate and farming in both the scientific and public consciousnesses. And as with any contentious issue, access to the evidence is vital. Whether it’s consumers or cabinet ministers, those looking to make informed decisions around food and farming need a solid foundation on which to base their actions. As such (and as part of a wider move towards ‘open access’ in research), this month also saw the launch of [the Rothamsted Repository](#).

The searchable database of every Rothamsted publication spanning 175 years (many of which are freely available*) has proved immensely popular, with a five-fold increase in month by month downloads over the course of its first full year.

Prominent



One 2019 paper** has racked up an Altmetric Score of 768 (already our 4th highest ever)

**Spatial and habitat variation in aphid, butterfly, moth and bird phenologies over the last half century. *Global Change Biology*, 25(6), 1982–1994, June 2019

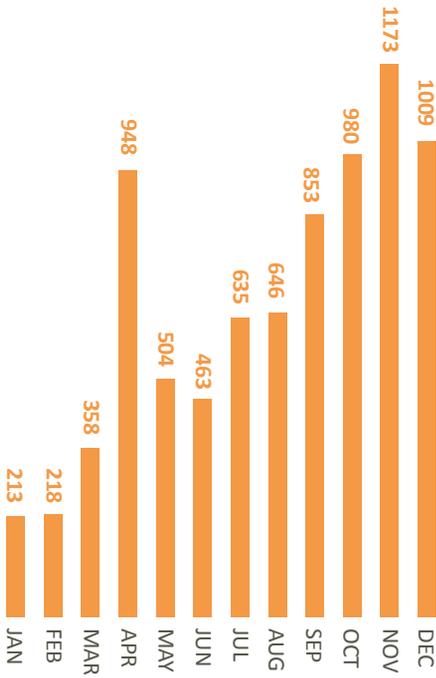
Prolific



We produced a publication a day (343 publications in 2019)

*27,926 total publications (1617 open access)

Downloads per month 2019



Popular



Monthly downloads of papers topped 1000 by year's end.



BIM'S EYE VIEW

Bim Afolami is **Member of Parliament for the Hitchin and Harpenden** constituency which has been home to our HQ for over 175 years. After a tumultuous year at home and abroad, we asked Bim for a politician's sense of whether Rothamsted's place in the world has changed.

Rothamsted Research has a national and worldwide reputation. Whenever I get up to speak about business or R&D in the House of Commons, the Business Secretary starts his response by praising Rothamsted and the work that goes on here.

When I was on a high level trip to China with Sir David Lidington (at that time effective Deputy Prime Minister), I was in a meeting with some of the most senior people in Beijing, and on introducing myself as MP for Harpenden I received a similarly glowing response about the importance of Rothamsted and the respect with which it is held. There is no comparable agricultural research institute in the world.

Yet Rothamsted knows that the world is changing rapidly.

It is no longer enough to be scientifically at the top. We always need to be thinking about operationalising our scientific discovery so that it can have practical application. To help solve climate change, to increase agricultural yield whilst using fewer pesticides and strengthening the long term health of the soil, to broaden our relationships with universities, businesses and central government so that the best science is helping inform decision making about UK innovation policy.

This is just a part of some of the work that Rothamsted is already doing and will continue to build on during the 21st century.

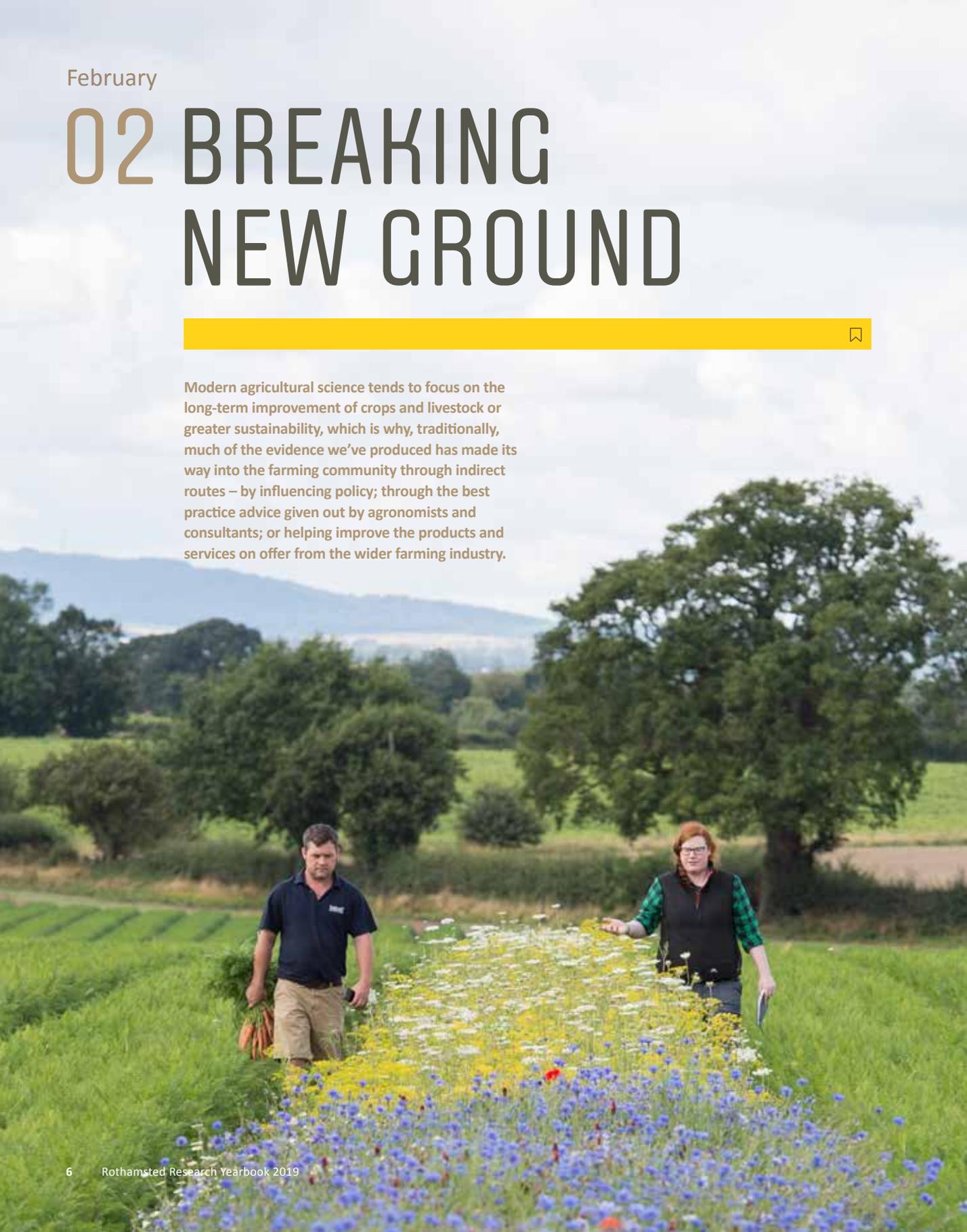
The future is bright.

February

02 BREAKING NEW GROUND



Modern agricultural science tends to focus on the long-term improvement of crops and livestock or greater sustainability, which is why, traditionally, much of the evidence we've produced has made its way into the farming community through indirect routes – by influencing policy; through the best practice advice given out by agronomists and consultants; or helping improve the products and services on offer from the wider farming industry.



DATA DRIVEN

We are involved in several initiatives using tech to share data with farmers:

However, with demands to change practices coming from both inside and outside the industry – not to mention the shifting political landscape, it's becoming clear there is a gap in the market for quick wins that boost efficiency, productivity, or sustainability of farmers. There is a huge appetite from farmers to find ways to improve their own operations and one way for Rothamsted to achieve that is to work at the level of individual farm businesses to provide test cases that can be rolled out elsewhere.

Which is why in February we launched **FarmInn**, a new fund for farmers who want to do innovative on-farm research, with all eligible costs covered and free access to Rothamsted's world class expertise and facilities. Part funded by AHDB, the aim of FarmInn is to provide real world, scientifically robust solutions to the challenges currently faced by UK agriculture. Four projects have been funded so far and we have other exciting projects in the pipeline. Funded projects include; a project to investigate the impact mixtures of wheat varieties have on disease resistance, competitiveness against weeds and soil health; the effect of cross-drilling in winter wheat; beef quality from permanent pasture; and starter fertiliser requirements in conservation agriculture systems.

We also published a study into England's farmland this month which found **key earthworm types** are rare or absent in two out of five fields – but which led to the majority of farmers affected vowing to change the way they farm.

The #60minworms project, the results of which were widely reported by the likes of the Today programme, Springwatch, **The Guardian**, and **The Sun**, was the first comprehensive worm survey concentrating solely on farmland and was carried out by farmers themselves – 57 percent of whom said they would change their soil management practices in response to the findings.

The **Farm Crap App Pro** is a collaborative project between Duchy College and Rothamsted to develop an easy to use, accurate and reliable way to manage and record slurry spreading information and data on manure. The app allows UK farmers to complete whole field nutrient management plans using the latest data from RB209 and share information with their advisors.



The **Nondo app** is part of the Smart Armyworm project run by Rothamsted Research and ICIPE and funded by the Bill and Melinda Gates Foundation. Together with our collaborators we are working to monitor fall armyworm right across Kenya, using radar to track insects as they fly and digital pheromone traps, which tell us when the moths are active in the field. Nondo helps growers identify the insects in their field and link them to pest management advice from CABI.



The **Croprotect** app provides farmers and agronomists with guidance on pest, weed and disease management in the UK, especially in situations where effective pesticides are not available and alternative approaches are required. The two-way system is building a detailed picture of specific challenges growers face as conventional pesticide options are diminished such as black-grass in winter wheat and flea beetle in oilseed rape.



Based in Australia, **iMapPESTS** aims to boost on-farm pest management through rapid and accurate monitoring and reporting of airborne pests and diseases.. A custom-built, mobile surveillance unit, known as a 'sentinel', has been developed to incorporate a number of smart trapping devices. It includes automated spore and insect traps developed by Rothamsted scientists.





Iran

We've published several papers on soil quality indices, erosion of agricultural land and wind erosion of agricultural soils.

China

Our partnership with the China Agricultural University continues, together with Royal Society funded work on erosion and soil loss in intensively farmed areas

India

Following an inception workshop, the TIG3RESS project got underway, screening traits for genetic diversity within Indian wheat production.

Ethiopia and Malawi

The Geonutrition project, in partnership with the University of Nottingham, the British Geological Survey and the London School of Hygiene and Tropical Medicine, seeks to reduce micro-nutrient deficiencies and will test the efficacy of eating flour enriched with zinc and selenium from fertilizers.



Kenya

With Kenyan researchers we've developed an early warning system for the invasive Fall Armyworm. Radar and ground traps covering 7,000 km² are keeping an eye on this destructive crop pest.

Myanmar

A recent Rothamsted International Fellow has been studying the genetic variation and nutritional values of tea leaf varieties.

Australia

The first mobile pest surveillance unit, known as a 'Sentinel', was unveiled in September in South Australia. The sentinel uses two Rothamsted designed spore traps and our unique insect suction trap.

ROTHAMSTED AROUND THE WORLD



March saw us travel to Casablanca, where along with Mohammed VI Polytechnic University (UM6P) and Cranfield University from the UK, we officially launched a new endeavour to help develop the next generation of Moroccan scientists and engineers.

The initial phase of the partnership, which is focusing on the delivery of seven agricultural

research projects and the creation of a Centre for Doctoral Training, is supported by OCP Group, one of the largest exporters of phosphate fertilisers in the world.

But that wasn't by any means our only foray into the wider world – with these maps giving just a flavour of where else we've been working.

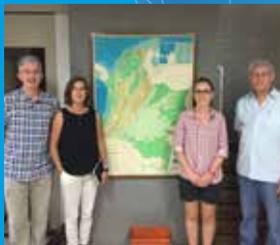


Mexico

Together with local partner CIAD, our researchers are investigating the mechanisms during the reproductive growth of wheat that could deliver heat tolerance.

Brazil

Our enduring partnership with Embrapa continues – including investigating the chemical signalling below ground between insects and plants.



Colombia

In partnership with CIAT and the University of Reading, this Newton Funded research focuses on identifying heat tolerant strains of beans – as well as the molecular level mechanisms for this trait.



GOOD CHEMISTRY



The Tailoring Plant Metabolism programme is delivering novel and improved traits in two bespoke crops, camelina and willow, through predictive re-programming of their metabolism. Our goal is to exploit fundamental understanding of plant metabolism to expand the value chains of crops.

A pilot-scale platform was established for the production of plant-based omega-3 fish oils and their validation in human and animal studies.

Large scale, multi-year field trials of product-selected willow varieties have been established, with view to validation and assessment of the commercial potential of “designer willows” producing high-value products

Screening the chemical composition of the National Willow Collection held at Rothamsted revealed a treasure trove of useful phenyl glycoside molecules, including a family of novel compounds, some with potential anti-cancer activity.

The first genes encoding phenyl glycoside biosynthetic pathway enzymes have been cloned and characterised.

April

04 THE DEVIL IS IN THE DETAIL



Against the backdrop of a very high profile, but subsequently much criticised, study suggesting all insects would be extinct within a century (see right), April saw the release of another landmark publication involving the Rothamsted Insect Survey – the world’s most comprehensive insect monitoring programme.

Looking at the timing of various natural phenomena over a period of half a century, the analysis provided yet further evidence that climate change has resulted in the steady advancement of Spring. More than that, it revealed hitherto unknown geographical and ecological subtleties in the impact this has had on the egg laying and migration of more than 250 species of insects and birds.

But perhaps most alarmingly, it dashed hopes that shaded habitats such as forests are shielding some populations from the destabilising effects of global warming. As The Guardian put it, insects ‘have no place to hide’ from climate change.

That the causes of insect declines are more complex than has previously been suggested was again highlighted in another Survey-derived paper later in the year that shows that whilst British moths have been in general decline for several decades, populations seem to rally every once in a while in the shape of mini population booms.

Whilst the full picture continues to elude us, it’s predominantly thanks to the Insect Survey that we have any pieces of this jigsaw at all. The one thing we can say, however, is that jumping to conclusions based on incomplete data is not helpful.



The Rothamsted Insect Survey Last year...

15 million records were provided to academics, policymakers, students and NGOs.

120 aphid bulletins, RIS Remarks and light-trap newsletters were sent out to the agri-industrial sector, volunteers and conservationists.

18 new mitochondrial aphid genomes

were assembled and annotated, and a LAMP assay to detect barley yellow dwarf viruses was completed.

New suction traps established in Inverness, Belfast and Kent brings the total to more than 89 traps.

The latest tech using radar, lasers and bioacoustics allowed us to distinguish – sometimes in real time – small insect species based on their shape, flight characteristics, and even colour.



Fact or fake news:

THE INSECTAGEDON

Dr James Bell, Head of the Rothamsted Insect Survey (RIS) considers the evidence for an immediate insect extinction.

“A German study in 2017 by Hallmann and colleagues found an 82% decline in insect biomass since 1989 and a related article which appeared in the journal Science titled ‘Where have all the insects gone?’ also received widespread attention.

*But it was the 2019 paper by Sánchez-Bayo & Wyckhuys that really **ignited the scientific community in cooperative disagreement**, due to issues around geographical, taxonomic and methodological biases that have purportedly undermined both the peer review process and insect conservation efforts.*

Predictably, the media loved it although Sánchez-Bayo & Wyckhuys’ (2019) claim that 40% of insect species are threatened with extinction, has been dismissed by many. That’s not to say that insects are faring well, because many scientists agree anecdotally that insect declines have happened in their lifetime, it’s just the rate of decline that is in dispute.

As for the RIS, we’ve previously found that declines in insect biomass have occurred at one of four sites investigated but this downward trend was primarily driven by a decline in abundance of one species of relatively heavy fever fly. Aphids on the other hand have shown little sign of change in annual totals over the last 50 years – despite significant changes to their phenology driven by climate and adaptations in life cycle traits.

Conversely, moths have seen some dramatic declines in numbers alongside a shift in the timing of their lifecycles. Two-thirds of 337 species studied declined over a 35-year study and a fifth of the species declined more than 30% in 10 years. Moth declines were worse in southern Britain, with a 40% decrease in total abundance, while there was no overall change in northern Britain where declines in some species have been offset by increases in others.”

The Verdict:

These and other studies highlight that standardised long-term data is best placed to answer questions concerning declines that are often nuanced when trying to understand the longer trends. However, combining long term data from many sources and studies, it is unquestionable that some insects are declining at a rapid rate and changes in policy and conservation practice are urgently needed.

Also in April



New research examined how fungi ‘tasting’ their host plants during infection could help fight Fusarium Head Blight, and a human health trial showed how plant produced omega-3 fats are just as effective nutritionally as fish oil.

FROM THE EARTH TO THE SPOON



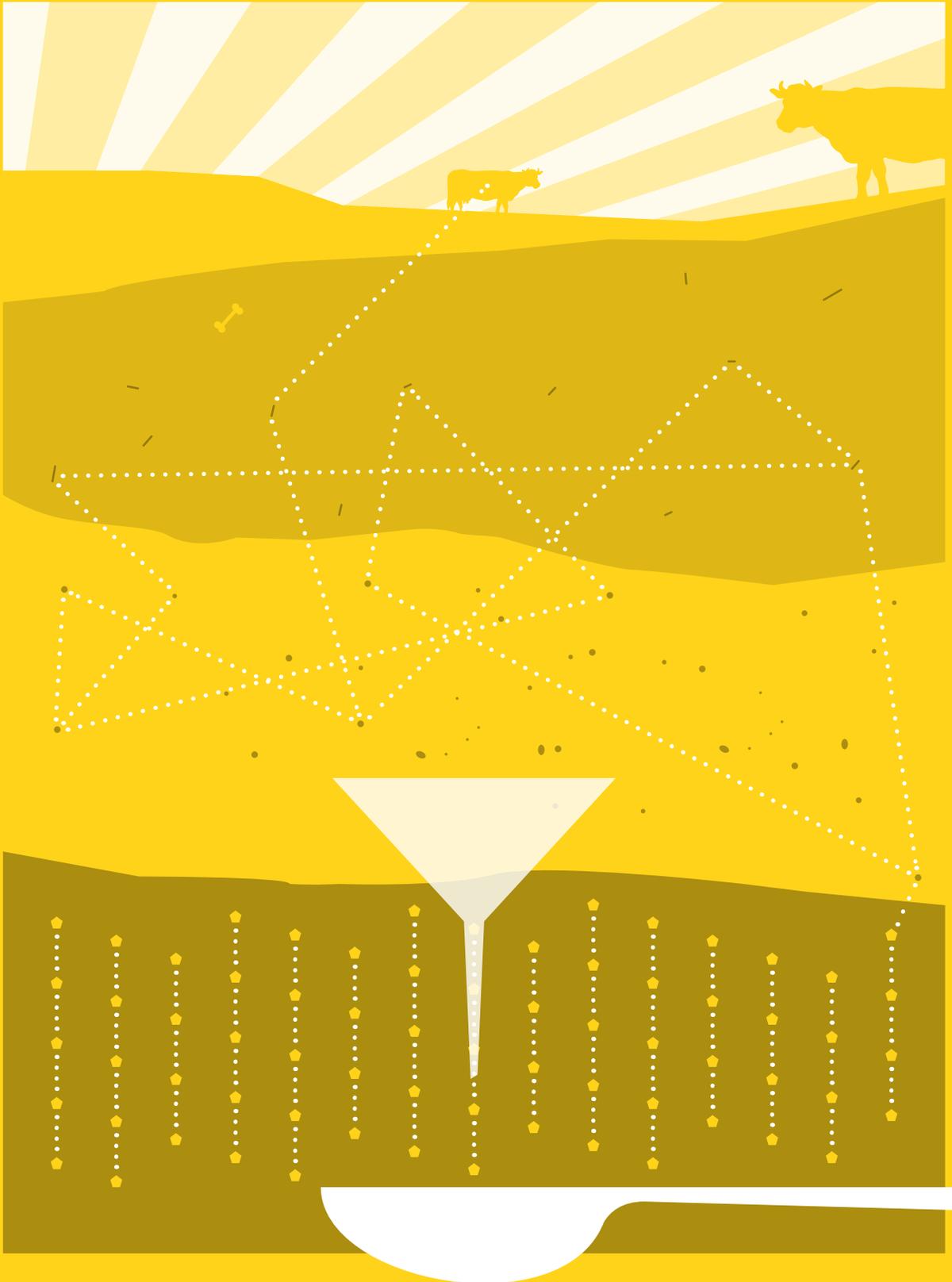
We are disentangling the complex interactions between the physical, biological and chemical processes that underpin how nutrients get from the soil, via our food, to us – and asking how we can make this journey more efficient.

The S2N programme has made significant progress in its first two years: 165 publications, £8.1M of additional funding across 53 new projects, including 23 PhD studentships.

We have developed a ‘theory of soil’ that shows how soils’ organic carbon content, structure and microbial activity are intimately linked. This new understanding of how soil works will help the identification and healing of damaged soils.

We have developed a set of interconnected simulations, from the microscopic to landscape scale, which are allowing us to see the effectiveness of nutrient flows in arable and livestock systems – and it’s already being used to help commercial farms across the UK.

Drawing on a broader understanding of health, our integrated vision allows us to account for both the nutritional value of food alongside its environmental impact – allowing consumers and policymakers to make better choices.



May

05 NOTHING VENTURED...

From our Victorian founder kick starting the fertiliser industry, through development of the key chemical used in mosquito nets, to the planting of our latest GM field trials last May, Rothamsted has always been at the forefront of the application of science.

The jump from lab bench to marketplace has traditionally been a considerable one, but with a pressing need for solutions – and the agritech sector booming – the clamour to narrow this gap is growing.

Which is why, in addition to our ongoing AgRia and SHAKE programmes, to help the next generation of scientists to become more commercially aware, we launched 'Why Not You?' a series of articles, videos, and workshops that both encourage and inform researchers who are thinking of making the leap and commercialising their work.

One of the first Why Not You? endeavours was a hackathon, the Sustainability Challenge, which asked teams of early career researchers to solve one of three key problems facing the

agricultural sector, with their solutions judged by agrichemical giant BASF during a 'Dragon's Den' style pitch at their headquarters in Germany. It was such a success, that two of the teams went on to develop their ideas further.

Our newly convened **Science and Impact Advisory Board** also met for the first time in May, with a brief to evaluate not only the scientific quality of Rothamsted's research programmes, but also the impact the research is having on the farming and food industry, society, and the environment, via amongst other things, innovation.

Also in May



A study showing the impact the **habitat adjacent to a field has on its weeds**, and GM expert Professor Jonathan Napier **commented on the problems facing the EU** when policing GE ingredients in food imports.



AgRIA



AgRIA (Agri-Tech Research Innovation Accelerator) is all about bringing together small and medium-sized businesses (SMEs) and academics to work together on challenging problems in agri-tech.

The £1.6M fund is supported for three years by the European Regional Development Fund and is led by Rothamsted Research in partnership with the University of Hertfordshire, University College London, Cranfield University, Herts Green Triangle, and Rothamsted Enterprises.

AgRIA projects are short and intense, and each of them runs for six to nine months. Total project costs are up to £65,000 and each project is focused on one or more of the following themes: soils, water and environment; internet of things; high value products; sustainable and green products.

The first cohort was made up of five teams, whilst the second was launched in March 2020 consisting of seven teams. The final cohort of AgRIA will be launched in September 2020 consisting of another seven teams.

Examples of businesses funded under AgRIA include: **Phytoform Labs**, **Babwe Barton Enterprises**, **uWatch**, **Merralls Consulting**, and Sustainable Resource Management Solutions.

June

06 PUTTING YOU IN THE PICTURE



June is always a busy time for events – whether we're involved with academic conferences, farming industry trade shows or public science fairs. Here's just some of the audiences we interacted with this year.

Herts Show

At least 150 strawberries were squished over two days as families were encouraged to extract their DNA.



Soapbox Science

Two of our scientists took to soapboxes in Milton Keynes Shopping Centre to talk about their science.



British Science Festival



New Scientist Live

Fighting the stereotype that agriculture is a low-tech, low-skilled and slow moving industry.



Also in June



We discovered growing glyphosate resistance in blackgrass; whilst China's Vice-Minister for Agriculture and Rural Affairs, Yu Xinrong, visited our HQ.

Cereals19

Must be the wettest cereals on record! We lost a marquee to bad weather before the event even started...

Big Bang SW

Our scientists met around 350 extremely optimistic and energetic young people that loved learning about optimising agriculture to reduce greenhouse gases.



And closer to home...

Year round we host hundreds of visitors from every corner of the globe who want to see our research in action.



BLOOM OR BUST?



It is no secret farming cannot carry on as it has – but by measuring the contribution of biodiversity and a healthy farm environment to sustainable farming, we can change for the better.

Intensive sampling of soils and crops on over 20 commercial wheat fields covering the wheat growing area of the UK has identified a key set of physical variables that explain variability in yield within and between fields.

A large manipulative field experiment is now well established on 18 commercial farms trialling the novel approach of sowing wildflower strips down the centre of fields. Early results indicate benefits for invertebrates delivering pest control and pollination services.

A large-scale grazing experiment trialling the interaction of multi-species herbal leys with different grazing strategies has demonstrated the benefit of cell grazing to sward productivity.

A landscape model has been used to identify trade-offs between the many services delivered by agriculture including food production and regulation of water and greenhouse gas emissions. The model has been used to optimise strategies that balance services across different soil types.



MUCH AT STEAK



Our North Wyke Farm Platform or ‘farm lab’ really demonstrated its worth this year, as meat eating came under public scrutiny as never before. The west country beef and sheep farm – where all the relevant environmental, agricultural and economic parameters are measured 24/7 – provides an unrivalled level of detail in our understanding of the impact livestock farming practices have on the environment.

This year saw two major additions to the site – a new [sheep housing facility](#) opened in July, which not only allows flocks from different experimental treatments to be housed separately over the winter, but its high-tech pens allow scientists to study different ways of rearing and producing lamb – and examine whether a switch away from red meat is good for the environment in the UK.

And on a similar theme, this year also saw the start of what has been [dubbed the ‘vegan trial’](#) – where livestock have been replaced by wheat to see if, with a shift towards predominantly plant-based diets, some of the UK’s pastures could instead be converted into productive arable land.

Other important studies to come from the ‘farm lab’ this year were an investigation into the [climate impact of reseeding pasture](#), and a [comparison of traditional and recycled phosphate fertilisers](#).

Also in July



We teamed up with the UK’s oil seed rape growers to [test the levels of insecticide resistance and parasitoid infestation levels](#) in cabbage stem flea beetles; whilst we also [celebrated 100 years since the data analysis techniques that shaped the modern world](#) were first developed at Rothamsted.



A WORLD WITHOUT LIVESTOCK

Livestock scientist and Head of our North Wyke ‘farm lab’, Professor Michael Lee, argues the polarising climate-livestock debate risks us missing the ‘sweet spot’...

There can be no doubt that our current consumption and production practices are not aligned to planetary and human health. The food we eat should be driving our health not undermining it, and agricultural practices should be at one with nature not destroying it. But can everything that is wrong with our diet and agricultural production be put at the door of ruminant (cattle and sheep) livestock, as some would make us believe?

The evidence is certainly not there to support a world without livestock as being the panacea for human and planetary health. But this is not a simple black and white message with a simple direction of removal solving all our ills. Livestock have a critical role to play in a circular nutrient economy from soil to plate – returning nutrients (especially C to soil) and utilising by-products from food and co-product supply chains; at the same time as delivering vital bioavailable nutrients to improve the health of the nation.

However, these rewards of livestock do not come without risk as they are more environmentally damaging than plant-based agriculture and over intensification to reduce emissions has critical welfare implications. Finding the sweet spot for the level of livestock for human and planetary health is challenging and is the focus of the research at Rothamsted using globally unique facilities such as the North Wyke Farm Platform.

To help unpick this complexity and develop easier messages for the public to understand and critically take action upon, regular dialogue with the media is key – this has been a major component of our work over the last 12 months as we have actively engaged with national and local TV, radio, and newspapers, as well as social media through blogs and tweets.

August

08 SHAKING IT UP



Within two weeks of the UK's hottest ever day, the IPCC had released its [Climate Change and Land report](#) and Goldsmiths became [the first UK university to ban meat from its menus](#), further stark reminders of the likely consequences – be they environmental or social – of further carbon inaction.

But what if, instead of being the villain, farming could become a climate hero?

That's the idea behind the [SHAKE Climate Change venture](#), an exciting new collaboration within agriculture and food production that is supporting entrepreneurs and start-ups who are combating climate change with their science or tech-based ideas.

More than a typical accelerator scheme, it brings together funding from the Societe Generale UK Foundation, with leading expertise in science, technology, and business as provided by mentors from Rothamsted, the University of Hertfordshire, Cranfield University and UCL.

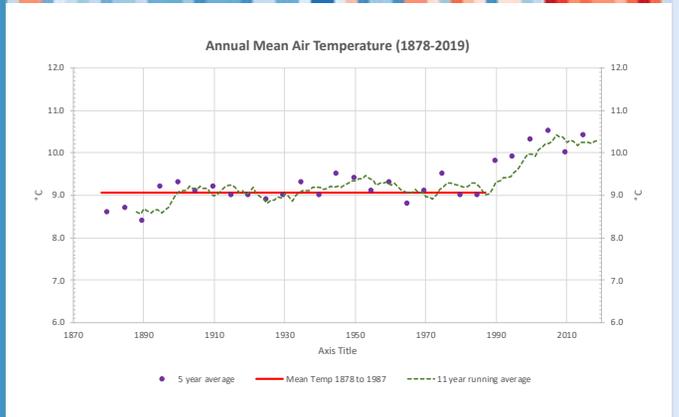
August saw the first workshop for the programme, the start of a process which [culminated in the first cohort of three successful businesses being selected](#) – but not after being put through their paces during a nerve-wracking pitch to the investment panel.



Also in August



Dr Sam Cook [spoke to the Financial Times](#) about the latest advances in the bio control of pests.



2019 – THE HOTTEST DATA IN YEARS

We've been collecting weather data at our HQ for more than 140 years, and in recognition of our global importance to climate change monitoring the **World Meteorological Organisation bestowed Centennial Recording Station status** upon us at a ceremony in March.

Overall, 2019 was wetter, sunnier and warmer than average.

- **The reading of 36.7°C on 25th July was the highest ever recorded at Rothamsted.**
- **February of 2019 was the warmest ever recorded, with a monthly mean maximum of 10.9°C.**
- **Winter 2019 was the sunniest on record.**

Temperature records began in 1878. Sunshine records began in 1890.

Weather datasets are available from the [website](#) including total monthly rainfall 1853–2018 and a record of extreme weather events since records began in the mid-19th century.

WORKING SMARTER



Our unique ‘Smart Crop Protection’ approach goes from gene to landscape, delivering more targeted and sustainable control of weeds, diseases and insect pests.

We published the first UK ‘resistance risk’ for glyphosate resistance in blackgrass, receiving widespread media attention as well as contributing to the first national economic costing of herbicide resistance, published in Nature Sustainability.

Together with the University of Sheffield, IBM, Hummingbird Technologies, and Precision Decisions we are working with a network of farmers to tackle the blackgrass problem using novel technology and artificial intelligence.

We developed a new tool for diagnosing barley yellow dwarf virus, which is being widely used, generating increasing interest from levy boards and agronomists. We also launched a new project to develop real-time disease surveillance and fungicide resistance monitoring tools in Brazil.

We have developed a methodology to edit the genome of a key lepidopteran pest. This will help in deciphering the molecular mechanisms underpinning insecticide resistance and the development of the next generation of pest control technologies.



09 TOO MUCH OF A GOOD THING

For as long as humans have tended livestock or planted crops, farming has been focused on channelling as many nutrients into our food as possible. And whilst yield increases drove the growth and development of human civilization, manipulating the natural cycles of essential minerals in this way has always required a careful balancing act – as it's one that has consequences for both people and planet.

Phosphorus provides a good example. Essential for plant growth, it's been added to crops the world over in one form or another for millennia – through manure, bone meal and later (thanks to our founder, Sir John Lawes) manufactured fertilisers.

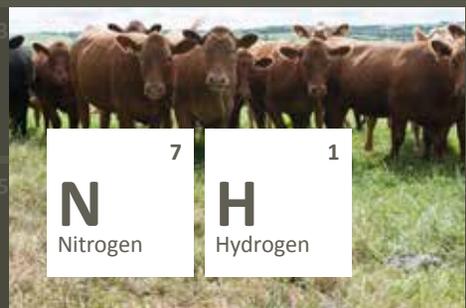
Modern phosphorus fertiliser is produced from phosphate rock, a mined resource with a patchy global distribution and whose continued supply is hotly disputed, as Dr Martin Blackwell [explained to The Guardian newspaper in September](#). Not only that, excessive use of phosphate is also causing widespread pollution that leads to algal blooms and dead zones in rivers and seas.

With 2019 also being the [International Year of the Periodic Table](#), here's just some of the work we are doing to help the world make better use of its fundamental building blocks.



Decoding soil health

You might be surprised to learn that soil is a product of genes – the combined effects of billions of fungi, bacteria and other soil dwelling microorganisms. Carbon, we've discovered, is literally the glue holding this massive ecosystem together and without it, soil structure deteriorates, influencing the genes controlling how bacteria and fungi behave and metabolize. These findings open the door to helping degraded soils recover their ability to hold water and prevent losses of greenhouse gases.



Cutting the crap

Unlike other air pollutants, ammonia emissions are rising – with the majority coming from livestock farming. Aside from the environmental impacts, NH_3 can inflict serious respiratory and heart conditions on all of us. So we're helping find better ways of muck spreading, storing manure, and reducing waste when feeding animals.



P
15
Phosphorus



Houston, we've got a problem

Without phosphate fertiliser there would be major food shortages, but when it washes from farmland into rivers, lakes or seas it fuels explosions of algae which choke aquatic life.

Our research focuses on smarter fertiliser use, recycled alternatives to rock phosphate derived fertilisers, improving its uptake by plants, and reducing its losses from fields.



S
16
Sulphur



The downside of cleaner air

Thankfully, pollution no longer dumps eight million tons of sulphur onto UK soils each year. But it does mean our crops aren't getting nearly enough. This lack of sulphur makes the harmful chemical acrylamide much more likely to develop when potatoes and cereals are cooked at high temperatures – something we are urgently looking to address through detailed genetic studies.



N
7
Nitrogen



When less is more

The manufacture of nitrogen fertiliser requires a great deal of energy, which if fossil fuels are used, contributes to climate change. Excessive use of fertiliser, a common problem the world over, can poison waterways, acidify soil and lead to the release of another potent greenhouse gas, nitrous oxide. We've advised governments the world over to help them produce guidance for farmers, remove subsidies and improve manufacturing, whilst closer to home, we're developing crops that make better use of this important element.

GREEN MACHINES



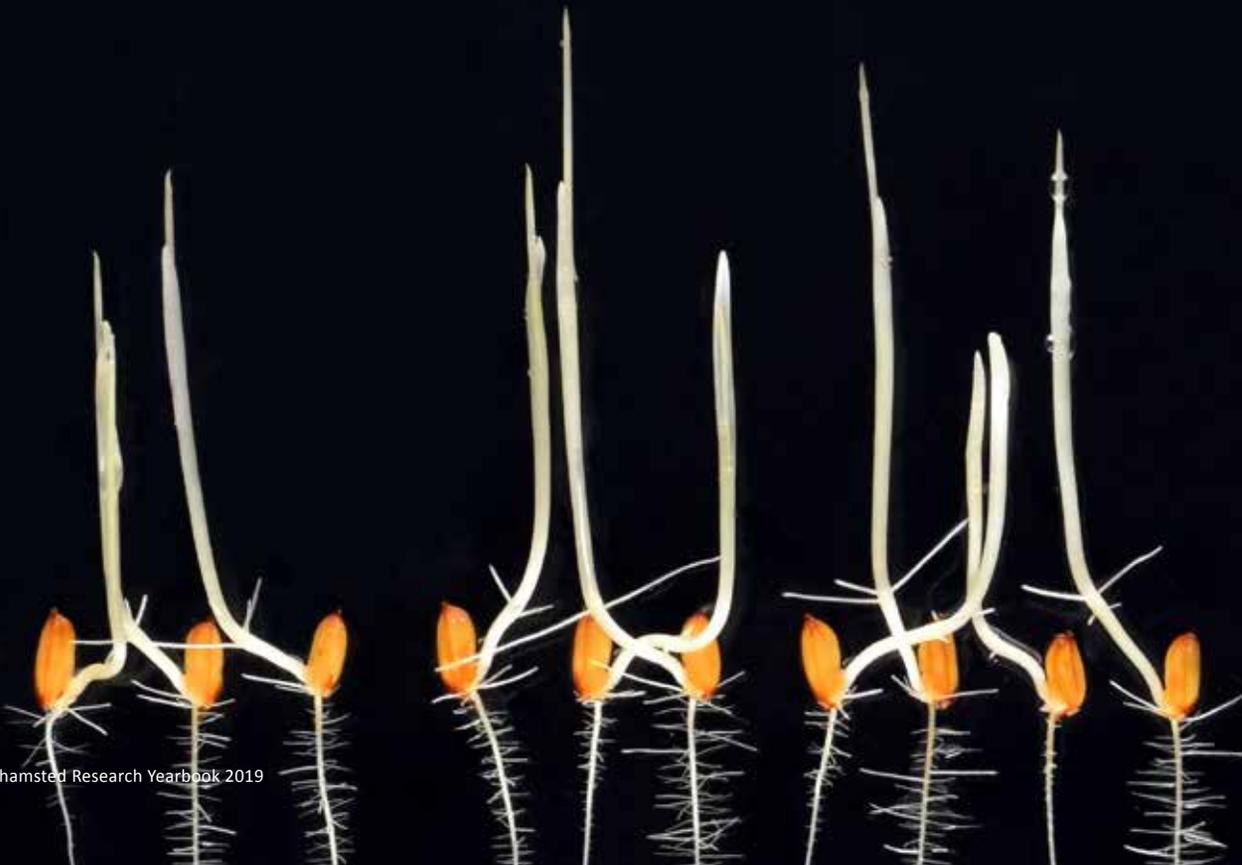
A number of events in October demonstrated how far we have come with our ability to engineer plants – with our Tailoring Plant Metabolism programme turning plants into ‘living factories’ that will improve human and planetary health.

First up Dr Peter Eastmond published a paper reporting on the production of human milk fat substitutes in plants. With most infant formulas relying on a less beneficial type of plant fat, this breakthrough could provide new, cost-effective and improved forms of infant nutrition for those babies that cannot be breast fed.

Autumn also saw the harvesting of the UK’s most comprehensive GM field trials to date; designed to evaluate camelina lines engineered with a range of added-value traits, including designer lipids and increased yield.

That was followed by our main funder, BBSRC, announcing that Rothamsted will lead one of four UK consortia awarded a total of £14M to explore the fundamental biology of living systems. The collaboration with UCL and Cambridge University aims to shed light on how protein synthesis is controlled.

And Rothamsted will also lead a consortium developing new rice varieties that can be grown with less water than in conventional rice paddies, benefiting low-income farmers and the environment.





Also in October



The UK Government's Chief Scientific Adviser, Sir Patrick Vallance **visited our HQ**; we launched the **Global Long Term Experiment Network**; and Professor Michael Lee **spoke to The Guardian** about livestock and climate.



REGULATION OR RESOLUTION?

Despite Brexit, there's no end in sight for the GM/GE debate, says Professor Nigel Halford

In recent years the GM debate has been reinvigorated with the advent of genome editing (GE), a technology that was not heard of when the EU's GM regulations were being drawn up. Those defined a GMO as an organism in which the genetic material has been altered in a way that does not occur naturally – a very wide definition which was never fit for purpose.

The EU's GM regulations also include a 'Mutagenesis Exemption' for plants carrying mutations induced by chemical or radiation mutagenesis; techniques widely used in plant breeding since the mid-20th century. GE in its simplest guise also results in the introduction of mutations but, unlike the older techniques, these mutations are targeted to specific genes. Nevertheless, the European Court of Justice (ECJ) ruled the Exemption did not apply to plants produced by GE. In so doing, it ignored the broad consensus of scientific opinion.

If the ECJ ruling is allowed to become the basis for the EU's long-term position on GE (which has still not been formally set out) Europe will miss out on the GE revolution just as it did the GM revolution a generation ago. Many argue that Brexit offers a chance for the UK to move to a science-based regulatory system, more in line with our other trading partners – but the fact that the EU will remain the major market for our food exports will make divergence difficult.

The debate is set to go on for some time yet.

TOMORROW'S WHEAT



Designing Future Wheat is a UK cross-institute coordinated programme aimed at the genetic improvement of wheat both in the UK and globally.

Despite intensive wheat breeding efforts, current European cultivars are far from their optimum, and a large genetic yield gap still exists. A unique study, the first of its kind, estimated that yields of 13 t/ha could be achieved across Europe if their genomes were ‘fine-tuned’.

Image analysis via machine learning has been developed to extract and quantify important crop features – such as ear abundance – from images collected by our field Scanalyzer and from cameras deployed on drones.

A pan-genome for the septoria leaf blotch fungus *Zymoseptoria tritici* has been successfully assembled based upon 12 strains collected from various European locations.

We’ve found underlying genetic variation in an important plant metabolic pathway that relates to grain number, biomass and plant height; that mutations in one specific stem-elongation gene cause other changes in plant shape that might help wheat to avoid diseases; and several new dwarf lines displaying potential improvements in architectural and grain quality traits.



OUR GREATEST ASSETS

It's nigh on impossible to work at Rothamsted and not be aware of its proud history and the unique position it holds within the UK's scientific heritage. But sometimes, whilst caught up in the day to day, it's easy for such achievements to slip from the mind. Which is why, with the end of the year approaching, we were glad to be reminded of some of what makes Rothamsted so special.

For instance, our unique data sets – not just from 176 years of the world's longest running experiment or the 55 million samples we've amassed as part of the world's largest insect monitoring programme – but lesser known ones like the world's only specialist database on the disease-causing genes of microorganisms. This is now highly relevant because its thanks to PHI-base that we know the threat of super-bugs arising has been seriously underestimated.

You can read about the Insect Survey and our one-of-a-kind 'farm lab' elsewhere in these pages, but have you heard of the Scanalyser? The UK's biggest 'phenotyping platform' can spy on a field of wheat 24/7, using its various onboard cameras and sensors to chart the growth, development, and even metabolism of individual plants below. And if that wasn't enough, it became an unlikely social media star when a video about it became our most popular ever post on Twitter and Facebook.



November also saw the 2019 Highly Cited Researchers list announced, and alongside 23 Nobel laureates, two Rothamsted staff were named among the global elite. For Professor Steve McGrath, it was his 18th consecutive appearance, and this time he was (again) joined on the list by Professor Peter Shewry.

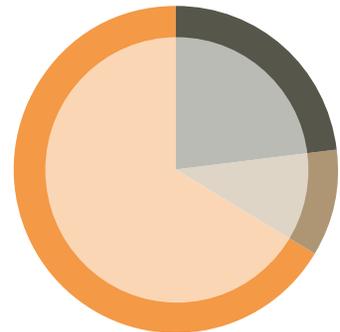
Which perfectly illustrates that, regardless of our globally unique facilities, data sets, and discoveries, it's our staff that have made us what we are today. They have, and always will be, our greatest assets.

Rothamsted Staff



Our 389 staff hail from 44 nations.

■ Business Support	23%
■ Operational Services	10.5%
■ Science	66.5%



Also in November



Henry Dimbleby, who is leading the UK's Food Strategy visited us; whilst we relaunched the indispensable Croprotect app.

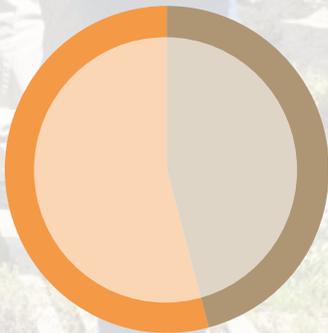


Rothamsted PhD students



Along with 12 of the UK's top universities, we're supervising 79 early career scientists.

■ Male	46%
■ Female	54%

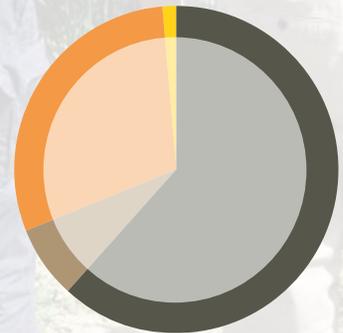


Rothamsted funding



We won over £15m of additional research grants in 2019.

■ UK Government	£9.3m
■ European Union	£1.1m
■ Industry	£4.5m
■ Other	£0.2m





December

12 NEW BEGINNINGS



It was with much sadness that we said goodbye in December to our Chief Executive and Director, Professor Achim Dobermann.

Bringing [five successful years at the helm to a close](#), Achim fulfilled a long-held desire to return to his native Germany.

[Professor Sir John Beddington](#), Chair of the Board of Trustees extended his thanks for all Achim's hard work during his 5 years as Institute Director, commenting that Professor Dobermann had done an excellent job of raising the profile of the Institute and that he was leaving it in a stronger position than it had been in when he arrived.

Reflecting on his time at the Institute, Professor Dobermann said: "Rothamsted is a wonderful and hugely important agricultural research institute. We have worked hard in the past five years to advance our science, become more innovative, develop new and stronger partnerships and have more impact on future farming.

"I think we have made great progress in all these areas. I feel that the time is now right for new leadership to take this even further."

Under Professor Dobermann's strategic vision Rothamsted Research went from strength to strength, cementing its place as one of the leading agricultural research institutes in the world.

From forging closer links with the farming and agri-tech sectors, to being an enthusiastic champion of early career researchers, throughout his time here Achim helped our science achieve impact and our staff achieve their potential. He will be missed, but we look forward to maintaining links with him in his new role as chief scientist with the International Fertiliser Association.

Also in December



We helped demonstrate [herbicide resistant blackgrass could cost £1 billion](#) a year; and also showed the untapped genetic potential of wheat [means its yield could be increased markedly](#).

DIRECTOR'S OVERVIEW



2019. A year where climate concerns, international politics and demographics collided, with the fallout sending shockwaves through the entire food and farming sector. And if that wasn't enough, the tail end of the year saw a global pandemic arise, resulting in a crisis that will no doubt leave a permanent mark on all our lives.

But whilst conditions are currently challenging, we believe there are three reasons to remain optimistic:

Resilient

In the face of such upheaval for the farming industry, change is necessary. And inevitable. The fundamental question, though, is how? As recent events have shown us, our response to situations can sometimes be as damaging as the situations themselves. With so much at stake and so little wriggle room, we must get this right.

Regardless of whether they are man-made or natural, the greater resilience needed to counteract uncertainty requires a deeper understanding of how systems operate.

As demonstrated across these pages, Rothamsted's research is firmly focused on doing just that – from gene to landscape. By understanding how important and often finite nutrients get from the soil via our food to us (and conversely, where along this chain they are lost) we are developing interventions that make farming more efficient and more cost-effective, whilst improving the health of people and planet.

Relevant

By making farming systems better at delivering the nutrients we need, we require less land and inputs to feed ourselves. By finding new and better ways to combat pests and diseases, we can make chemical interventions safer – or even unnecessary. And by identifying traits that result in hardier varieties and breeds, we protect our food supply from the increasing environmental pressures and unstable climatic conditions that lie ahead.

Taken together, these approaches will drive food production to become healthier and harmonised with the world around us.

Responsive

Whilst change can be scary, having been in operation for almost 180 years allows us some institutional perspective. From the Victorian era need for artificial manures, through post-war demands for increased production, the crop protection requirements of the 70s and 80s, the food security concerns of the 90s, and today's focus on sustainable intensification, there have always been new demands and new hurdles to overcome.

Science and innovation are key to meeting these challenges, and our research programmes and new innovation activities established in 2019, were designed to meet the needs of an ever evolving sector. Through collaboration with many people within that sector, our track record shows we've been very successful in doing so – by anticipating society's demands and recognising the environmental impacts before they arise.

Rothamsted

All of which is why, despite the unprecedented nature of the task ahead, we refuse to believe that the challenges we face cannot be overcome. So whatever 2020 and beyond throws at us, we are confident that Rothamsted Research, working with BBSRC and our many partners across academia and business, is in excellent shape to tackle it.

We hope reading about some of our 2019 successes has inspired confidence, and we invite you to join our endeavours in overcoming what lies ahead.

With my very best wishes,

Professor Angela Karp,
Director and CEO



THE WAY AHEAD

As we were going to press, the Covid19 pandemic was disrupting societies across the globe. This will create huge challenges both for scientists and farmers. The turmoil has highlighted the critical nature of food supply both in the UK and elsewhere and the need to strengthen our production systems.

Rothamsted is uniquely placed to deliver insights into agricultural practices and how they can be made sustainable and resilient. We look forward to facing up to this challenge in 2020 with the roll out of a comprehensive plan to fully digitise our systems.

Our science has never been needed more.

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