



ROTHAMSTED
RESEARCH

2021

YEARBOOK

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TIPPING POINTS

Balance is the key



Professor Angela Karp
Director and CEO

Year two of the Covid-19 pandemic brought the food and farming industry a whole new series of challenges. Supply chains that had managed to bend-not-break during the first 18 months of the crisis were put under severe stress as rebounding demand exposed how key resources were in very short supply.

From fruit pickers and HGV drivers, to semi-conductors and carbon dioxide, unexpected shortages caused real concerns for businesses, politicians and consumers alike.

Whilst the turmoil of the last few years was – we hope – an extreme example, it does demonstrate the fragility of our globalised food system. The sort of shocks we witnessed this year could well become all too familiar as the climate emergency worsens, and it is more vital than ever that we build further resilience into the system.

Events have shown us just how susceptible we are – and the time to rectify that is now.

We must step up the pace and intensify all efforts to adapt to climate change and find solutions.

Much of Rothamsted’s science is focused on doing just that – and the news that genome editing research in the UK will now be easier allows us to rapidly improve our crops to withstand the global changes we know are coming, with more floods, droughts and disease risk set to be the norm.



Rt Hon George Eustace MP said GE could help
“tackle some of the biggest challenges that we face – around food security, climate change and biodiversity loss”



From L to R Prof Nigel Halford, Rt Hon George Eustice MP, Jo Churchill MP, Prof Angela Karp, Prof Gideon Henderson, Dr Julian Smith

Ahead of a [visit to Rothamsted](#), to coincide with the publication of the results of the Government's genome editing (GE) consultation exercise, the Secretary of State, Rt Hon George Eustice MP said GE could help "tackle some of the biggest challenges that we face – around food security, climate change and biodiversity loss" and the current Government's aim was to foster innovation so crops would be "stronger and more resilient to climate change".

But alongside adaptation, we also need to work hard and work quickly to minimise those climate impacts caused by our food consumption habits, with farming and land use contributing a quarter of all society's greenhouse gases.

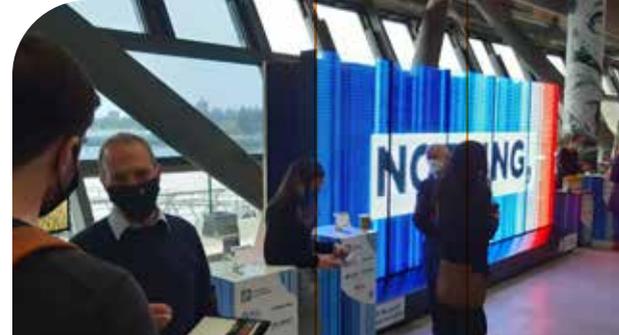


As delegate after delegate at COP 26 clearly articulated, if we let things go too far, then the ramifications may be too great for even science to mitigate.

Whilst it had its critics, intense scrutiny of those Glasgow-made agreements is a sign that world governments are waking up to the realities of climate change. Although strong influences were clearly at play, it's also a clear demonstration that society's biggest challenges won't so much be in finding climate solutions – rather in finding the right balance of solutions.

Dietary choices are a good example. We know we need to eat less meat, but what do livestock farming communities do if we stop altogether? And in farming areas where crops cannot easily be grown, will a meat-free future be seen as a good idea?

Likewise, there is a desire to reduce reliance on agrichemicals – but will the subsequent diminished yields (in tandem with more mouths to feed), inevitably lead to either more nature converted to farmland or higher food prices?



Jon Storkey at #COP26 communicating sustainable agriculture research on the UKRI exhibition stand.

These are the sorts of dilemmas that society must wrestle with over the coming years and decades, and it important that research institutions such as Rothamsted act not just as knowledge generators or knowledge brokers, but also make themselves available as impartial analysts and interpreters advising policy makers so they can make the most informed decisions they can.

We need to go much further down the path set out at COP26 and implement changes that are not only effective but also equitable and compatible.

Angela Karp

Professor Angela Karp, Director and CEO

FUTURE-PROOFED FOOD

2021 could prove to be a real turning point for the UK's food and farming sector.

The publication in July of the [National Food Strategy](#) by restaurateur Henry Dimbleby made [national headlines](#) with its calls for a sugar and salt tax, as well as proposals for fruit and veg to be available on the NHS.

But dive deeper into its 290 pages and you will find a slew of recommendations relating to land use, investment in research, and ways to help farmers transition to a post-Brexit, low carbon future.

Commenting on the report, Rothamsted Research Director and CEO, Professor Angela Karp [welcomed the idea](#) of a £500 million challenge fund to promote innovation on farms and agri-tech start-ups.

“Society will only successfully tackle the challenges laid out in this report by embracing scientific solutions – by developing more nutritious foods that are accessible to all, that are grown in harmony with the natural world, and that allow farmers to earn a fair living.

“The UK is home to some of the world’s foremost experts in agricultural research, experts who have already made great strides in addressing the issues laid out in this report. What is needed now is for industry, government and civil society to help us to build on these breakthroughs and realise them in the wider world.”

One area of breakthrough that received a significant boost this year was genome editing, as the Government [announced plans](#) to remove many of the barriers scientists face when performing GE field trials, a move widely welcomed by the academic community – hopefully opening the door for CRISPR edited foods to eventually be on sale in UK shops.

Perhaps one of the first such items will be bread with reduced cancer risk, as [reported on the front page of The Times](#) in September. Professor Nigel Halford and his team were given the go-ahead this year to perform field trials of their low acrylamide wheat. Created using gene editing technology, the wheat has very low concentrations of the amino acid asparagine, the precursor of the carcinogen, acrylamide which forms at high temperatures.



“Society will only successfully tackle the challenges laid out in this report by embracing scientific solutions”

Rothamsted Research Director and CEO, Professor Angela Karp

The Dimbleby report also identified numerous other threats to human and planetary health from our current eating habits – not least the country’s “tragically high death rate” from obesity or food production being responsible for a quarter of our total greenhouse gas emissions.

One area of contention in the report was its call for a 30% reduction in meat consumption – although it steered clear of suggesting a meat tax, calling it “politically impossible”.

A Rothamsted [study released around the same time](#) concluded a tax on red meat to help curb climate change could do more harm than good, with a cost to the UK of £242M against £100M in climate savings.

Dr Taro Takahashi, the agricultural economist who led the research said the economic losses will not only be borne by livestock farmers, but everyone in society.

“Solely from the climate change perspective, our results unambiguously support everyone else’s finding: that a red meat tax can reduce GHG emissions. But unfortunately, this is only half the story, because the same tax could also force grazing livestock farms out of the industry – even when grassland is actually the most sensible land use at that particular location.

“As well as impacting consumers and farmers, the knock-on effects will be felt right along supply chains as well as rural communities that support and are supported by farmers.”

Rather than a blanket tax, a better solution would be to look at which areas of the country are best kept as cattle and sheep farms, and which would be better turned to other uses such as crop production for human consumption, agroforestry, and provision of ecosystem services.

“This would involve a more nuanced approach of weighing up the carbon savings against the amount of nutrients produced and the impacts on the economy, both locally and nationally.”

Our North Wyke farm also provided news that would be welcomed by shepherds and shepherd’s pie eaters alike – by establishing a clear link [between the weight of lambs early in their life and meat quality](#).

Currently, 35% of lambs going to market have meat that is considered too fatty, but this new finding will allow farmers to concentrate on giving their flock the best start in life, as well as looking to breed for lambs that are heavier once weaned.

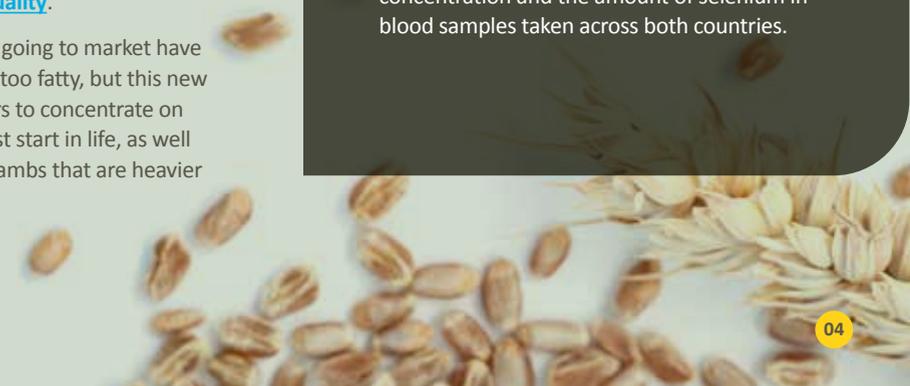


Africa’s soil ‘postcode lottery’

Published in *Nature*, the first surveys of cereal grain micronutrient composition in sub-Saharan Africa at a within-country scale found that whether a child develops serious health problems from poor diet is essentially a ‘postcode lottery’.

The joint Africa-UK research team [analysed thousands of cereal grains and soils](#) as part of the project to tackle so called ‘hidden hunger’ in Malawi and Ethiopia, where they found large geographical variation in micronutrients in staple cereal grains.

Further analyses showed there were clear localised relationships between grain selenium concentration and the amount of selenium in blood samples taken across both countries.



OUR GLOBAL REACH

Norway

A leading team of researchers from Norway, the United Kingdom (including Rothamsted) and USA are identifying the semiochemicals that are associated with Atlantic salmon susceptibility to sea lice and developing tools to reduce lice infestation in Norwegian marine systems.



The Philippines

A collaboration between the International Rice Research Institute, Kasetsart University, NIAB and Rothamsted Research will be looking at improving the nutritional value and digestibility of rice to address double burden malnutrition in the Philippines and Thailand.



Myanmar

Rothamsted International Fellow Dr Khin Myo Myint from the Myanmar Ministry of Agriculture conducted a study on genetic variation and nutritional values of Myanmar tea leaf varieties with Dr Jane Ward.



Nigeria

Dr Jon West and Rothamsted International Fellow Dr Boniface Kashina from the Institute for Agricultural Research, Ahmadu Bello University used new imaging techniques for pre-visual detection and phenotyping of Potato virus X-induced symptoms in the tomato, *Solanum lycopersicum*.

74%
OF ALL
ROTHAMSTED'S
RESEARCH

is published with international partners

Ireland

University College Dublin will be working with Prof Adie Collins at North Wyke on a project to look at Water Futures: Mitigation in a changing environment.



Austria

Rothamsted is participating in an EU-wide project (UNTWIST) to unravel the response of *Camelina sativa* to elevated temperatures and drought stress.

USA

USA – Colorado State University is partnering with Dr Dana MacGregor under the newly launched International Weed Genome Consortium to develop genomic tools and resources and to stimulate research for weed biology and management.



Zimbabwe

In partnership with CIMMYT and Zimbabwe's Food and Nutrition Council, Rothamsted scientists are addressing malnutrition in Zimbabwe with biofortified maize, studying crop management to policy and consumption.



India

Rothamsted International Fellow Dr Rupam Bhunia from the National Agri-Food Biotechnology Institute (NABI), together with Rothamsted's Pete Eastmond, studied how genetic improvement of rice bran stability could contribute to improved human health and nutrition.

Australia

In a world first for pest surveillance, the iMapPESTS' solar powered Sentinel 5 insect and spore trapper (incorporating Rothamsted expertise) was deployed to the field.





ALL CHANGE

From policy decisions to climate impacts, farming is adapting

With the phased introduction of three new [Environmental Land Management schemes](#) planned for the next two years, moving away from EU subsidies continues to be a post-Brexit concern for many within the farming community.

But in fact, research has shown that such schemes lead to more stable incomes compared with payments based purely on the number of hectares being farmed.

According to the [study of farms in England and Wales](#), dairy, general cropping, and mixed farms that received more agri-environmental payments had more stable incomes in the short and medium-term.

The only sector it didn't improve were farms in the so called 'Less Favoured Areas' – predominantly upland farms who graze sheep or cattle, which do not see the same stability benefits from agri-environmental payments.

The research also shows that farmers shouldn't put all their eggs in one basket, as those diversifying into a wider variety of crops or livestock receive more consistent year-to-year incomes.

One such new crop might be soybean, as other research from this year has shown [the crop could be more widely farmed in the UK](#).

Currently only grown in very limited quantities, soybean could be more successful across southern England and climate change will mean it could also be grown for profit as far north as the Scottish borders within just a few decades.

Lead author Dr Kevin Coleman said: "Yields would be enough to make it an economically attractive option for farmers, with the added benefits of reduced nitrogen fertiliser needs and the fact that soybean has very few pests or diseases here."

Recent advances in plant breeding have produced easy to harvest soybean varieties suitable for the UK's relatively cold, wet climate – overcoming what were the main barriers to take-up by farmers.

The weather's impact on crops was the subject of further analysis this year, when historical yield and weather data showed that winter wheat and spring barley [yields were greater under a typical 20th Century than 21st Century climate.](#)

Looking at monthly summaries of daily temperatures, rainfall, and sunshine hours at Rothamsted, researchers identified 10 distinct 'clusters' of yearly weather patterns that occurred from 1892 to 2016.

The annual weather cluster most dominant after 1991 generally had higher summer temperatures and more intense winter rainfall distributions but with a particularly dry June – and it is this weather pattern which was also associated with the lowest cereal yields.

And whereas crops have suffered under our shifting weather patterns, weeds are unfortunately doing better.

Plots on the world's longest running experiment, the Broadbalk wheat trial, which have never had herbicide show yield losses to weeds have been consistently increasing since the late 1960s.

A warming climate is one reason crops are now more vulnerable to weeds, coupled with a shift towards shorter crop varieties that get shaded out by the taller weeds.

Less than a third of the harvest was lost to weeds in the first ten years of the dataset, but between 2005–2014, this had risen to more than half.

Add in the rise of herbicide resistance, and the implications for food security are very clear.

“Weeds now represent a greater inherent threat to crop production than before the advent of herbicides and integrated, sustainable solutions to weed management are urgently needed to protect the high yield potential of modern crop varieties,” [warned weed ecologist, Dr Jon Storkey.](#)

32%
Reduction in yield
due to weeds
(1969–1978)



54%
Reduction in yield
due to weeds
(2005–2014)



DESIGNING FUTURE WHEAT

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

- Three years of field trial evaluation of new Rht-1 dwarfing alleles have identified beneficial traits for wheat breeders. Elite germplasm containing these introgressed alleles will be available to the breeding community in 2023.
- An important sugar regulator of spike architecture, grain size and number has been identified through gene editing.
- A 3D model of root water uptake has been compared against soil drying data to show how wheat might adjust the hydraulic architecture of its root system to optimally balance the use of ephemeral and secured soil water.
- Through the use of refined phenotyping methods and new aphid-resistant *T. monococcum* material, valuable resistance to aphids has been demonstrated as mappable using established populations with informative markers also validated for use. This high-level type of resistance has not previously been identified in hexaploid wheat. Capture of phloem exudates through the targeted removal of aphid stylets has also been achieved, and now undergoing optimisations for prospective work profiling phloem against germplasm with traits of interest.
- 45 mutation lines with premature stop codon for Zn transporters of TaZIP7, TaMTP1 and TaMTP3 have been identified, and the triple mutants and BC1F1 plants have been generated by three rounds of crossing and genotyping for each transporter. ZIP7 was localized in vascular bundles (in root, leaf and node), and aleurone and embryo (in grain).



In addition to well-established weed species, UK farmers [face new threats](#) too – such as rat's tail fescue, a grass weed that is already posing problems in France, Switzerland, Spain and Denmark – and is now starting to take hold in England and Wales.

The weed was the subject of a nationwide survey in the summer, jointly run by Rothamsted and NRI Greenwich, which aimed to better understand the spread of the plant and the threat it poses.

And lest we forget, in addition to weeds, plant diseases continue to prove a challenge for growers, with a report this year of early signs of [fungicide resistance emerging](#) in the fungus that causes light leaf spot on oil seed rape, and the news that a variety of the fungus that causes the disease, Phoma, on oilseed rape and other brassicas has been discovered [in Europe for the first time](#).

Some good news at least came in the form of a review summarising [recent advances](#) in the battle against Take-all, the devastating wheat root disease which can claim as much as half the crop.



Are trees the answer to wildlife-farming conflicts?

A 12-year, farmer-led agroforestry project launched in 2021 will investigate whether the practice is a viable way to address the climate and nature crises while maintaining productive farmland. [Involving seven farms in Devon](#), it will be the largest participatory research project to-date looking at silvopasture – the practice of integrating trees and livestock.

The farmers, who produce beef, sheep, venison and dairy, are expecting the trees to bring a range of benefits to their farming systems by enhancing the natural processes that underpin sustainable food production.

Three different planting designs are being trialled, tailored to the farm and the balance they wish to strike between open grazing and tree cover. The research will see farmers plant a mix of twelve native tree and shrub species, including oak, downy birch, aspen, alder and willow.

Alongside Rothamsted, who will be monitoring soil health, the project also involves Innovative Farmers, The Farming and Wildlife Advisory Group, the Woodland Trust and the Organic Research Centre.



SOIL 2 NUTRITION

Our Soil to Nutrition programme is 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.

- We established the importance of nitrogen fertilisation regime, land use and wheat genotype in shaping the composition of the root microbiome.
- We have published a unique set of nine soil metagenomes, representing over 600 Gb of sequence data generated from the Highfield Ley-Arable long-term experiment.
- Using a soil organic carbon to clay ratio, we can now define organic matter targets for specific soils and land uses. It has enabled us to determine soil organic carbon and soil clay contents quicker and at much lower cost than conventional laboratory methods.
- Environmental impacts of agricultural systems have traditionally been calculated per quantify of food produced, but this approach ignores the nutritional value of each food item, potentially misleading the public by favouring nutrient-poor commodities and thereby “empty” calories. We exposed this issue to scientific debate and developed a novel framework of life cycle assessment to internalise nutritional consequences of different farming strategies.
- Our modelling shows that an effective ‘Net-Zero’ transition of the UK’s agricultural sector requires spatially explicit and integrated cropping strategies, using perennial crops for bio-materials in food production systems to support terrestrial carbon sequestration.

HARNESSING FOR HARMONY

Mother Nature needs a hand

With protestors [gluing themselves](#) to Britain's motorways and the 'Red Alert' mantra of [COP26](#), climate change was once again front and centre this year.

Our [SHAKE programme](#) continued its support for visionaries and disrupters, with two further businesses receiving its unique blend of financial support and expert mentoring.

To date, the programme has invested £1.26 million in nine companies, which in turn has led to a further £3.2 million of additional investment into these ventures from elsewhere – a great testament to the value added by the SHAKE programme. By the end of 2022, the climate change impact of SHAKE is anticipated to be the same as removing 655,000 fossil fuelled cars from the road.

The sorts of innovative ideas behind these companies are exactly what is needed in the fight to make food and farming carbon neutral – especially when we consider that rewilding and other environmental remediation efforts can only do so much to redress the damage we have caused.

This was well illustrated by a [study this year](#) of samples from the world's longest running ecological experiment, Park Grass, which shows that some of the planet's most productive grasslands may have reached carbon saturation sometime near the beginning of the twentieth century or earlier – when the concentration of atmospheric CO₂ was only two thirds its current level.



By the end of 2022, the climate change impact of SHAKE is anticipated to be the same as removing 655,000 fossil fuelled cars from the road.

Similarly, two leading soil scientists warned that incentives for farmers to increase the carbon sequestered in their soils will become something of a [‘postcode lottery’](#), with those farming on sandy soils facing an impossible task to increase carbon stocks.

That’s not to say we shouldn’t be doing all we can to improve the status of our soils – just a recognition that these issues are more nuanced than many would have us believe and that the solutions aren’t simple.

Staying below ground, other research this year showed how chemical fertilisers reduce the number of nutrient solubilising bacteria associated with the roots of wheat. The addition of fertiliser [decreased the proportion of these bacteria that help make nutrients](#) such as nitrogen, potassium, phosphorous, iron, and zinc more readily available from soil.

On a similar note, analysis of soils from the long running Highfield Ley experiment showed how fertiliser use, ploughing and pest control had [created a ‘new world order’ in the soils](#), with beneficial bacteria muscled out at the expense of ‘killer fungi’ and nitrogen stealing archaea.

The results of both studies point to the idea that the addition of fertiliser means that plants no longer need to interact with these beneficial bacteria to access the nutrients required to grow. Fertiliser has essentially, short circuited the flow of nutrients through farmland soils.

As one researcher put it: “We rely on soil to grow almost all of our food, but perhaps surprisingly we know little about how the way we manage soils affects the microbial communities which support soil fertility, provide clean water and regulate greenhouse gas emissions.”





SMART CROP PROTECTION

Our unique approach to crop protection goes from gene to landscape, delivering more targeted and sustainable control of weeds, diseases and insect pests.

Whilst our Smart Crop Protection programme ended in 2020, outputs have continued to be generated and aspects of this research will be incorporated into the new research programme currently under development.

- We completed sequencing and annotation of the black-grass genome (with Bayer, Clemson University and the University of Copenhagen) and used it to reveal patterns of divergent evolution of non-target site resistance to herbicides.
- We also established a collaboration with Earlham Institute to sequence and annotate the orange foxtail genome.
- By using Insect Survey data on the first flight of aphids and artificial neural networks to understand if the RIS network was optimised for surveillance and monitoring, we showed that the network captured most of the UK crop landscape but there was a gap – which was quickly filled by a new suction trap.
- We started a new NERC-funded project (DRUID) that will mine the Rothamsted archive of insect samples, uncovering change in little-known insect groups that deliver important ecosystem functions, such as decomposition.
- We identified a new variant of *Plenodomus lingam* in the UK and on a new host, as well as identifying widespread reduced sensitivity to fungicides in populations of *Pyrenopeziza brassicae* in Europe.

One hundred not out – a century of Entomology

A century on from the establishment of an entomology department at Rothamsted under the guidance of A.D. Imms (author of the most important [undergraduate textbook on insects ever written](#)), and these invertebrates continue to form a major tranche of our research.

We are one of four institutions [awarded £2.3 million by UKRI](#) to provide definitive evidence on whether insects are in decline in the UK, to understand the key drivers threatening their existence, and to support the development of environmental policies to protect them.

The new project, which includes the University of Leeds, the University of Reading, and the UK Centre for Ecology & Hydrology (UKCEH) will undertake the most comprehensive analysis to-date of British insect populations from as wide a range of sources, and for as broad a set of species, as possible.

The impetus for that funding comes from alarming data such as found in the latest [‘The State of Britain’s Larger Moths’](#) report which came out this year.

Produced by a partnership between Rothamsted, wildlife charity Butterfly Conservation, and the UK Centre for Ecology & Hydrology, the report, the last of which was released in 2013, draws on tens of millions of records gathered through the Rothamsted Insect Survey and National Moth Recording Scheme (NMRS).

Rothamsted data shows the total abundance of larger moths in Britain [decreased by 33%](#) over a 50-year period between 1968–2017.

This third assessment of The State of Britain’s Larger Moths is dedicated to Dr Kelvin Conrad who passed away in 2018. His work on moth population trends at Rothamsted Research was the key driver for the first such report in 2006, which he co-authored.

Bees are another insect group of concern, especially in relation to the impact of pesticides upon them. There was much consternation last spring when it emerged the UK Government was considering allowing the use of previously banned neonicotinoid, Cruiser SB, by sugar beet farmers who were facing devastating crop losses to viruses transmitted by aphids.

As it was, the pesticide application wasn’t required – but what perhaps isn’t well known is that it was a Rothamsted model, [predicting aphid numbers and likely viral loads](#), that was the deciding factor in whether the pesticide-treated seeds would be needed.

Our bee research also uncovered some surprising insights this year – such as how [male bees act like men in nightclubs](#) and how flowers release their scent in response to the [electricity of a bee’s touch](#).

Tiny Dancers

Equally amazing is how our researchers have developed a way of identifying some of the world’s most devastating insect pest species whilst they are in flight – despite them being too small or quiet for conventional insect tracking technologies to pick up.

[Using LED sensors](#), the team were able to detect and record the characteristic flight of eight species based solely on their shadows when they flew through a light beam. By applying complex data analysis techniques to these flight patterns, they were then able to identify which species of weak flying aphid or beetle it was, with up to 80% accuracy.



ASSIST

It is no secret farming cannot carry on as it has, but our ASSIST research programme – in partnership with the UK Centre for Ecology and Hydrology – is measuring the contribution of biodiversity and a healthy farm environment to sustainable farming so we can change for the better.

- A study showed that grasses are [physiologically constrained](#) from taking up further carbon dioxide through declines in the time that stomata are open – even when nitrogen fertilisers are added to encourage their growth – and grasslands that have received high levels of nitrogen fertiliser are today taking up less nitrogen and yielding less than they were a century ago.
- Crops are more [vulnerable to weeds now](#) than before the advent of herbicides, according to a new study. Where herbicides have never been used, yield losses to weeds have been consistently increasing since the 1960s. This is likely due to a combination of factors including weeds doing better than crops in a warming climate, the shift towards shorter crop varieties that get shaded out by taller weeds, increased herbicide resistance, and weed species benefitting from increased use of nitrogen fertilisers.
- [A study of meteorological and crop yield data](#) from Rothamsted identified 10 distinct ‘clusters’ of yearly weather patterns from 1892 to 2016. The most dominant since 1991 has higher summer temperatures, more intense winter rainfall distributions and the lowest cereal yields. Five annual weather patterns which occurred frequently during much of the 20th Century have not recurred in more recent years, suggesting evidence of climate change in several more dimensions than mean temperature alone.
- [The Electronic Rothamsted Archive \(e-RA\)](#) continues to compile and make available key datasets and metadata. Examples in 2021 include time series of experimental plans and cropping on the Broadbalk Winter Wheat and Park Grass experiments, Broadbalk brown foot rot (*Fusarium spp.*) 1992–2009, Rothamsted and Woburn long-term liming experiments grain mineral composition data, and Park Grass Experiment lime treatments.
- Thirty-one journal articles, three book chapters and one thesis were published in 2021 that used or referred to data or new analyses of samples from Rothamsted’s Long-Term Experiments.

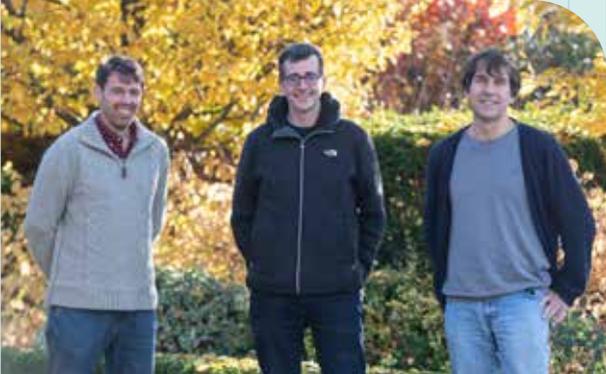
THE SCIENCE (OF FEEDING THE WORLD)

Regardless of whether we are boosting the nutritional value of food, developing more benign agriculture, or finding ways to improve the livelihoods of farmers globally, it all starts with the science.

From the genetic, biochemical and physiological mechanisms that make microbes, crops and animals tick, to the ceaseless flow of nutrients that binds the soil, water, and air to all living things, understanding is everything.

- Like discovering the importance of the promoter regions of wheat genes – long overlooked in favour of the protein coding section of the gene when it came to productive targets for breeders. Four years of painstaking lab work by Michael and Kim Hammond-Kosack found in fact that, rather than just simple on-off switches, these regions are [crucial in determining the nature of important plant traits](#). The finding means plant breeders can now ‘mix and match’ promoter and coding regions, opening up whole new avenues of investigation.
- Or when Dr Steve Thomas was part of the group to finally discover the proteins [responsible for dwarfing in wheat](#) – the key characteristic that lay behind the success of the 1960s green revolution. But rather than being an interesting scientific sidenote, the finding will have practical benefits as the research also explains why only certain parts of the wheat plant are affected by the dwarfing genes.

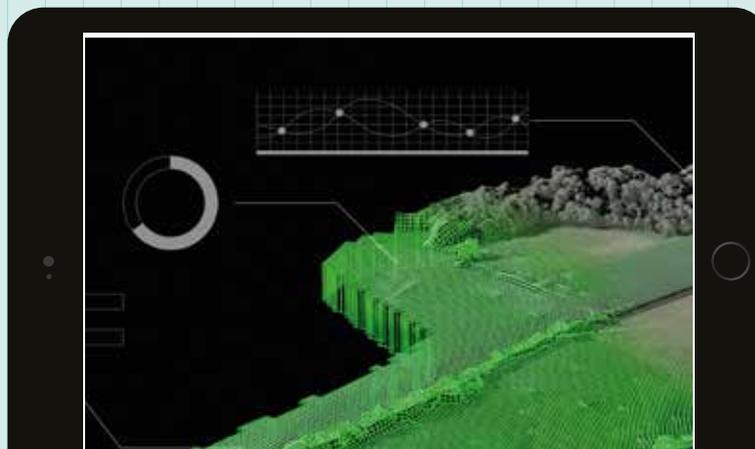
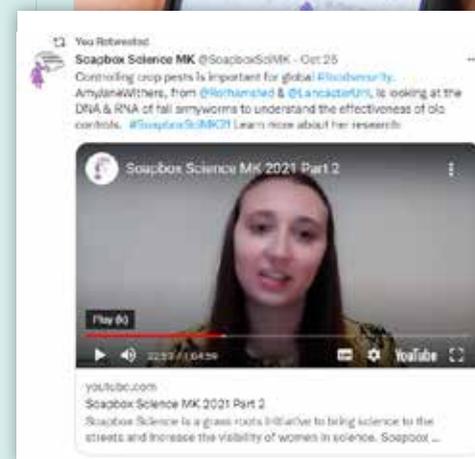
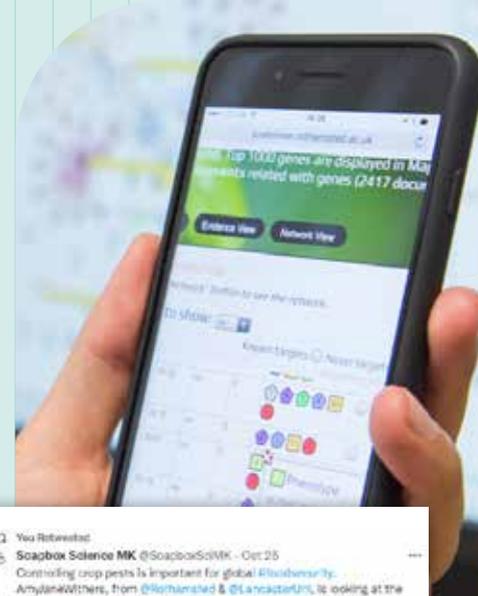




New faces for Rothamsted's science leadership

In 2021 Rothamsted was delighted to welcome three new senior science leaders. Joining from Bangor University, Professor Simon Willcock (left) is an expert in ecosystem services and the sustainable use of natural resources. He is developing large-scale social science studies to determine how farm-scale changes might impact other aspects of society. Professor Martin Broadley (centre) is one of Rothamsted's new Science Directors and Professor of Plant Nutrition at the University of Nottingham. His research seeks to increase our understanding of mineral nutrient dynamics in agriculture and food systems with a particular focus on improving the nutritional quality of crops for human and livestock diets. Also a new Science Director is Dr Julian Smith (right) who joined us from FERA. He provides leadership on science strategy, alongside engagement with UK and overseas governments, academia, foundations and industry. His science specialisms include national biosecurity, crop protection and seed systems.

- And how about organising the wealth of all this knowledge? Aimed primarily at plant and crop scientists, [KnetMiner](#) is described by its creators as the first 'gene discovery platform' for the biological sciences, unearthing previously unknown links between genes, gene networks and traits by searching across species and the boundaries between academic disciplines – a total of over 5 million relationships.
- It's not often we'd quote Sun Tzu's *The Art of War* – but 'know thy enemy' is good advice. From figuring out the [molecular biology of weeds](#), to how [aphids make their pheromones](#), to the population structure of one of Africa's [most troublesome pests](#), understanding threats to food production – and how best to tackle them – is vital if we are to feed the world sustainably.
- But we're not just here for the nasty things in life. Need a digital twin of your livestock farm? Right down to exactly mimicking grass growth, the amount of beef and lamb it produces, and the greenhouse gas emissions of its animals? [We've got you covered.](#)



TAILORING PLANT METABOLISM

Plants are a treasure trove of useful chemicals. Our goal is to exploit fundamental understanding of plant metabolism to make high value products and expand the value chains of crops.

Genome editing is playing an increasingly important role in the programme. Not only is it an invaluable tool to speed up discovery science, but it can also be used to tweak metabolism and development to improve crops.

Genome Editing

- Analysis of genome-edited poplar plants has helped our scientists understand how phenolic glycosides are made and which genes are most important. Phenolic glycosides are natural chemicals that have many uses including potential sources of sustainable industrial building blocks.
- Genome editing Camelina, an emerging Brassica crop, is also uncovering new genes important for controlling oil production in seeds.

GE and GM stacks

- The team is also using genome editing in combination with GM to further enhance plant metabolism and development to deliver new traits. In addition, field testing of GE Camelina plants under the UK's new Qualifying Higher Plant (non-GM) regulations has contributed vital evidence to policymakers as well as being a key step in assessing the real-world performance of the crop.

Product testing

- The team secured BBSRC funding to set up a biomass processing and development centre which will enable scale-up and testing of plant products from woody biomass and seeds.
- Together with collaborators at the Universities of Southampton and Stirling, oil from GM Camelina engineered to make omega-3 fatty acids was tested in both aquafeed and human feeding trials and found to perform as well as fish oil. This has positive implications for human nutrition, marine ecology, and agriculture. [Genetically modified plants are an alternative to oily fish for providing n-3 polyunsaturated fatty acids in the human diet: A summary of the findings of a Biotechnology and Biological Sciences Research Council funded project.](#)



A man in a blue suit and face mask is speaking to a group of people in a laboratory setting. He is gesturing with his right hand. In the background, there is a white cabinet with a sign that says "AIRFLOW CONTROLS".

POLICY MATTERS

As science and agriculture policy in the UK continue to evolve at pace, Rothamsted has sought to bolster its responses and proactively seek impact for its research outcomes.

Following on from last year's policy initiatives, 2021 saw progress in all of our main policy areas:

Gene technologies

Further announcements on post-Brexit changes to the regulation of GM and GE crops led to high levels of political and media interest. Rothamsted submitted its response to DEFRA's GE consultation in March. Five months later, the approval and planting of the UK's first ever GE wheat trial at Rothamsted in August meant the institute was ideally placed to play a lead role in the ongoing national debate. DEFRA Secretary of State George Eustice visited Rothamsted in October to announce the first steps in formulating new regulations: A less restrictive approach to on-farm GE field trials. Rothamsted also took part in a series of webinars on the international GE/M regulation landscape led by the US Department of Agriculture.

Sustainable farming futures

Rothamsted scientists continued to contribute to ongoing policy formation for the sustainable farming initiative and the proposed environmental land management payments system. Notable contributions were made to the development of Parliamentary Office of Science and Technology briefing notes on soils and water management.



Crop protection

In early 2021, the UK government agreed to derogate the use of neonicotinoid insecticides to counter the threat of virus yellows in sugar beet, spread by aphids. Use of the pesticide was only to be permitted if modelling undertaken by Rothamsted suggested that aphid numbers would be sufficiently high to risk substantial damage to the UK harvest. The insect survey used its ongoing monitoring capacity to assess the risk and concluded that numbers were likely to be low. As a result, the pesticide was not deployed, and a successful growing season was completed. Input costs were saved, and any potential environmental side effects avoided. It was a textbook demonstration of how sophisticated surveillance can deliver smarter, evidence-based crop protection.

Climate change

Rothamsted staff joined the UKRI exhibition stand at the November UNFCCC COP 26 meeting in Glasgow. Researchers also took part in a number of pre-conference online events and assisted UKRI in preparing a range of communications materials.

Delivering on Net Zero Bim Afolami MP

“As Chair of the All-Party Parliamentary Group for Renewable & Sustainable Energy, it was a pleasure to host my annual Net Zero sustainability conference at Rothamsted here in Harpenden. This year the programme focussed on the economic steps needed to finance the delivery of Net Zero commitments and discuss climate-positive policies that accelerate economic growth while protecting our future. There was a focus on business leaders from across different sectors comparing both the successes and challenges of rapidly decarbonising, and to pitch policy ideas that will support businesses large and small to operate and grow sustainably.

After a tour of Rothamsted, the programme was opened with a keynote speech by the Secretary of State for Business, Energy & Industrial Strategy, the Rt Hon Dr Kwasi Kwarteng MP. Through the work of his brief, he naturally recognised Rothamsted as the world-leading institution it is, making leaps in agroecological advancements for climate change resilient crop production.”

TEAM ROTHAMSTED

Rothamsted staff numbers

436

FULL & PART-TIME

55 PhDs 29 women 26 men

30
VISITING WORKERS

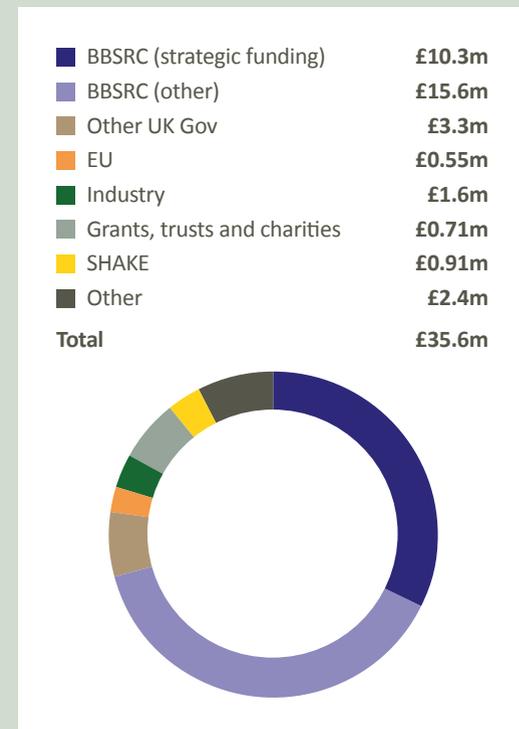
From 44 countries other than UK

Argentina, Australia, Bermuda, Brazil, Cameroon, China, Costa Rica, Croatia, Denmark, Ethiopia, France, Germany, Ghana, Greece, Hungary, Indonesia, India, Italy, Ireland, Japan, Malaysia, Malta, Mexico, Morocco, Netherlands, Nepal, Nigeria, Pakistan, Peru, Portugal, Romania, Russia, Senegal, South Korea, Spain, St Vincent & the Grenadines, Slovakia, Taiwan, Uganda, Uruguay, USA, Venezuela, Zimbabwe.

Rothamsted Funding

£35.6m

to March 2022



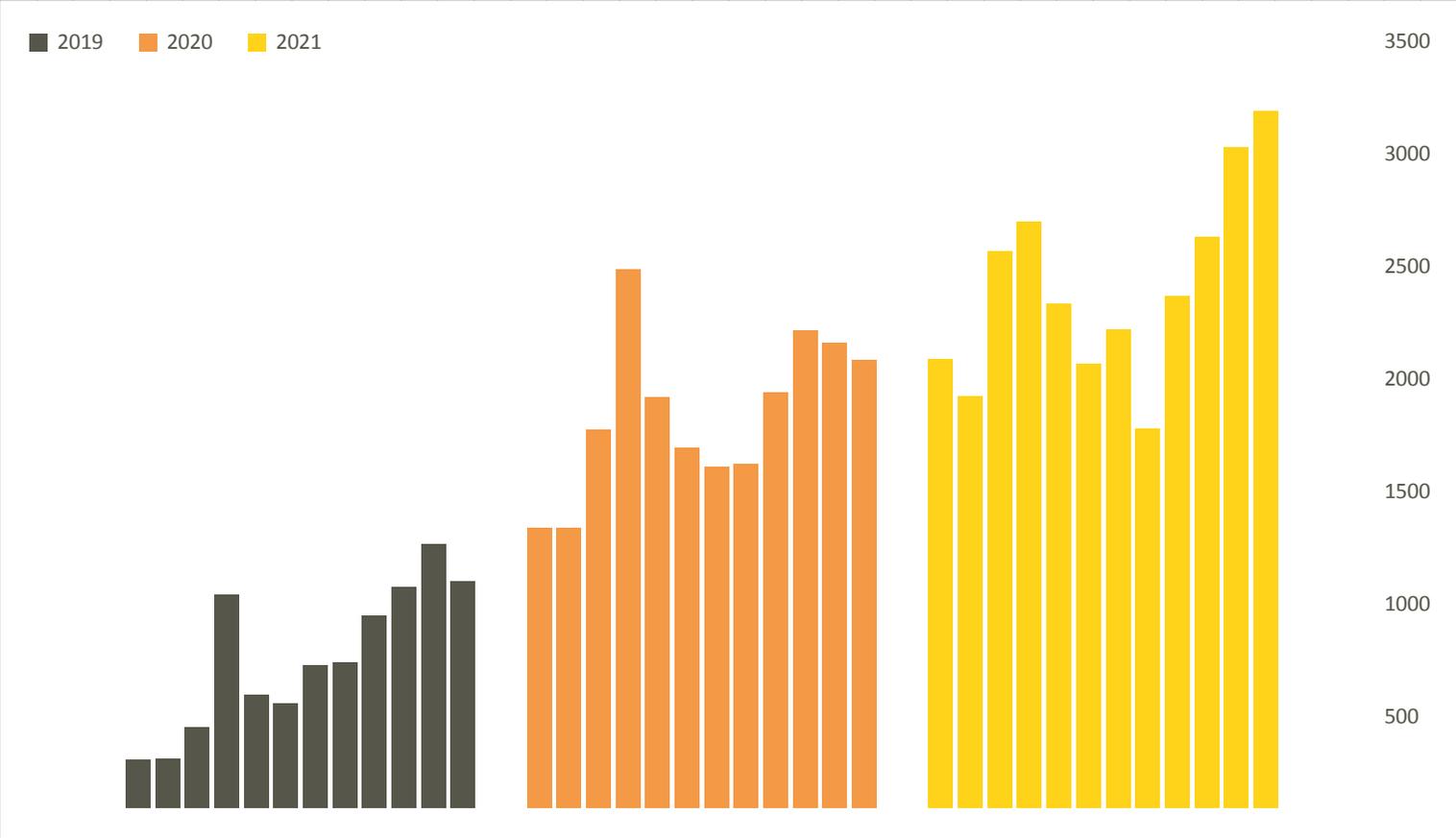
Repository Downloads

Three years on from the launch of the Rothamsted Repository and it continues to go from strength to strength.

The Repository is a digital treasure trove of pretty much everything we've ever published since 1843.

By the end of its first year, it had reached 1000 downloads a month – and as you'll see below*, downloads were double that throughout much of 2020.

We thought interest might have peaked, but as this year's figures show, interest has continued to grow, reaching a high of 3000 downloads a month by the end of 2021.





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