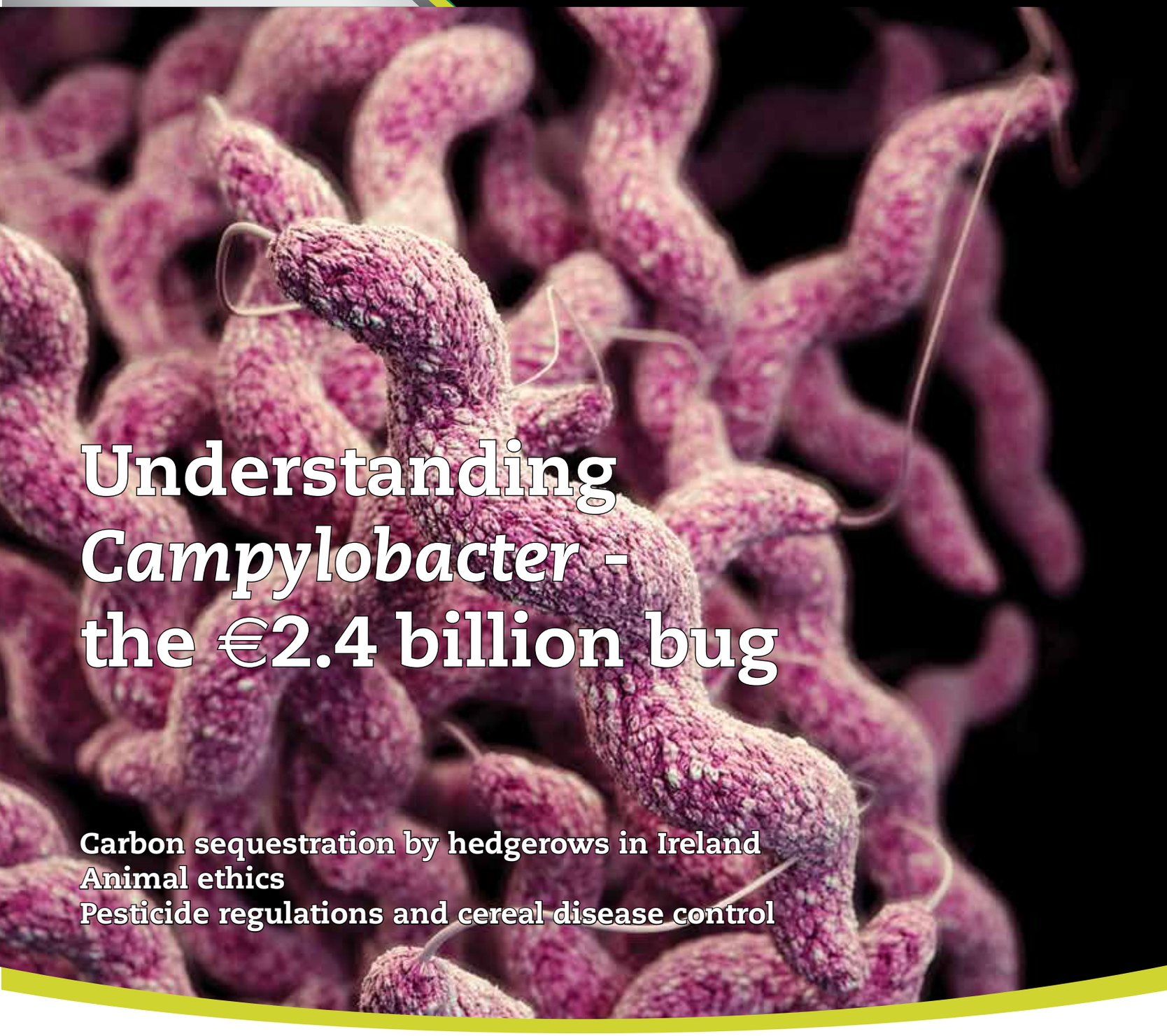
TEAGASC

Research

Volume 9: Number 4. Winter 2014 ISSN 1649-8917

Research and innovation news at Teagasc www.teagasc.ie



Understanding *Campylobacter* - the €2.4 billion bug

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TResearch is an official science publication of Teagasc. It aims to disseminate the results of the organisation's research to a broad audience. The opinions expressed in the magazine are, however, those of the authors and cannot be construed as reflecting Teagasc's views. The Editor reserves the right to edit all copy submitted to the publication.

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The important role of competitive research funding

Teagasc funds its research programmes through a mixture of grant-in-aid (block grant) from the Department of Agriculture, Food and the Marine (DAFM), competitive research funding, farmer levy, industry funding, and revenue from farm operations and other specialist services. The main sources of competitive research funding are the FIRM/Stimulus/CoFoRD programmes run by DAFM, programmes of other Irish funding agencies (Enterprise Ireland, Science Foundation Ireland, the Irish Research Council and the Environmental Protection Agency) and the EU through Horizon 2020 and its previous Framework programmes. This funding is essential to our programmes and operations. It allows us to expand our activity and hire post-doctoral researchers, and it also funds many of our Walsh Fellows, with both of these groups central to the Teagasc research model. Competitive funding usually involves collaboration, which is a very positive and essential dimension of modern research. Despite the downturn in the economy in recent years, the Government has maintained significant investment in research. Indeed, over the last three years, DAFM has awarded new competitive funding of over €85 million, with Teagasc researchers leading or collaborating in many of the projects funded. While national funding does, and will continue to be, the largest source of funding for Irish public research organisations, EU funding is increasingly important. The new Horizon 2020 programme will fund research to the value of €80 billion over the next seven years. Ireland has a target to win €1.25 billion of this, and Teagasc has committed to securing €19 million over the duration of Horizon 2020. Our performance in the first round of applications is encouraging, and in particular the success of the Landmark application (a project on functional land management led by Drs Rachel Creamer and Rogier Schulte), where Teagasc is the co-ordinating institution, is particularly welcome. The international collaborations in EU projects are particularly important for a small country like Ireland. Together, with our grant-in-aid funding, this national and international competitive funding provides a healthy mix of research funding for Teagasc.

Dr Frank O'Mara
Director of Research, Teagasc

An ról tábhachtach a imríonn maoiniú taighde iomaíoch

Maoiníonn Teagasc a chláir thaighde trí mheascán de na nithe seo: deontas i gcabhair (blocdheontas) ón Roinn Talmhaíochta, Bia agus Mara (DAFM), maoiniú taighde iomaíoch, tobhach feirmeoirí, maoiniú tionscadail agus ioncam ó oibríochtaí feirme agus ó shainseirbhísí eile. Is iad na príomhfhoinsí de mhaoiniú taighde iomaíoch ná cláir FIRM/Stimulus/CoFoRD a reáchtálann an Roinn Talmhaíochta, Bia agus Mara, cláir a reáchtálann gníomhaireachtaí maoiniúcháin Éireannacha eile (Fiontraíocht Éireann, Fondúireacht Eolaíochta Éireann, an Chomhairle um Thaighde in Éirinn agus an Ghníomhaireacht um Chaomhnú Comhshaoil) agus an tAontas Eorpach trí Fhís 2020 agus trína chláir Chreata roimhe seo. Tá an maoiniú sin riachtanach dár gcláir agus dár n-oibríochtaí. Cuireann sé ar ár gcumas ár ngníomhaíocht a mhéadú agus taighdeoirí Iar-dhochtúireachta a fhostú agus maoiníonn sé roinnt mhaith dár mic léinn d'Ánracht an Bhreatnaigh. Tá páirt lárnach ag an dá ghrúpa sin i múnla taighde Teagasc. Bíonn comhoibriú, ar gné an-dearfach riachtanach de thaighde nua-aimseartha é, i gceist le maoiniú iomaíoch de ghnáth. D'ainneoin an choir chun donais sa gheilleagar le blianta beaga anuas, tá infheistíocht shuntasach coimeádta ag an rialtas i dtaighde. Go deimhin, dhámh an DAFM maoiniú iomaíoch nua ar fiú €85 milliún é le trí bliana anuas agus bhí taighdeoirí Teagasc i gceannas ar roinnt mhaith de na tionscadail a maoiníodh nó bhí siad ag comhoibriú iontu. Cé go bhfuil agus go mbeidh maoiniú náisiúnta ar an bhfoinse maoiniúcháin is mó d'eagraíochtaí Éireannacha maoiniúcháin phoiblí, bíonn an tábhacht a bhaineann le maoiniú ón AE ag méadú. Déanfaidh an clár nua d'Fhís 2020 maoiniú ar thaighde go dtí luach €80 billiún sna seacht mbliana romhainn. Tá sé mar sprioc ag Éirinn €1.25 billiún den mhaoiniú sin a ghnóthú agus thug Teagasc tiomantas go n-aimseodh sé €19 milliún thar thréimhse feidhme Fhís 2020. Cúis spreagtha is ea ár bhfeidhmíocht sa chéad bhabhta iarratas agus tá fáilte go háirithe roimh an rath a bhí ag iarratas Landmark (tionscadal ar bhainistíocht fheidhmeach úsáide talún a raibh an Dr Rachel Creamer agus an Dr Rogier Schulte i gceannas air) mar a bhfuil Teagasc ar an institiúid chomhordúcháin. I gcás tír bheag amhail Éire, baineann tábhacht ar leith leis an gcomhoibriú idirnáisiúnta i dtionscadail an AE. I dteannta a chéile, agus mar aon lenár maoiniú deontais i gcabhair, meascán maith de mhaoiniú taighde do Teagasc atá sa mhaoiniú iomaíoch náisiúnta agus sa mhaoiniú iomaíoch idirnáisiúnta sin.

An Dr Frank O'Mara
Stiúrthóir Taighde, Teagasc

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Published on behalf of Teagasc by:
IFP Media, 31 Deansgrange Road, Blackrock, Co. Dublin.
t 01-289 3305 **f** 01-289 6406 **www.ifpmedia.com**
Design: Ciarán Brougham, Martin Whelan
Editorial: Oonagh O'Mahony

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Cover image of *Campylobacter* courtesy of Melissa Brower, Centers for Disease Control, USA.

Dr Bernadette O'Brien

Dr Bernadette O'Brien is a Senior Research Officer in the Livestock Systems Research Department at Teagasc Moorepark's Animal and Grassland Research and Innovation Centre.
At the National University of Ireland (NUI), Cork, Dr O'Brien completed a BSc in Dairying in 1982, followed by an MSc in Milk Cooling Rates in 1985 and a PhD in Milking and Mastitis in 1988.
In her current role at Teagasc, Dr O'Brien's projects include research into: innovative and sustainable systems combining automatic milking and precision grazing; automation in the milking process within a grass-based system; increasing efficiency of traditional technologies and exploring new technology on Irish dairy farms; seasonal variation in milk composition and minimising chemical residues of milk; and factors that impact on the processing quality of raw milk produced in Ireland.
Other research by Dr O'Brien has looked at on-farm labour efficiency with respect to labour input profiles, alternative milking frequencies, various calf feeding frequencies, and milking efficiency in conventional parlours; processability of milk; milk quality with respect to somatic cell count (SCC), hygiene and residues; and developing precision technologies for application on-farm.
Dr O'Brien has also been involved in coordinating (or PI) successful applications for research funding to organisations such as the Dairy Research Trust; Stimulus; SFI; FIRM and the EU.
Recent successful applications include: a Joint FIRM/RSF Initiative that reviews factors impacting on the processing quality of raw milk produced in Ireland; a Seventh Framework Programme exploring ICT tools for grazing management; a FIRM/RSF Initiative that researches precision nutrition for improved animal productivity, product quality and environmental sustainability; and a SFI Funding Initiative examining the use of precision technologies, technology platforms and computational biology to increase the economic and environmental sustainability of pasture-based production systems.
Dr O'Brien has published extensively. Her work includes 60 peer-reviewed papers; two thesis; six scientific book chapters; and one monograph, as well as newspaper articles, non-refereed journals and papers/summaries published in conference proceedings, among others.
Dr O'Brien's work has allowed her the opportunity to collaborate with the dairy industry and dairy research groups including international collaborations with research scientists at Wisconsin University (Madison), USA, and Massey University and Dexcel in New Zealand. Most recently, Dr O'Brien established and coordinated a network of research scientists in six European countries in joint research in automatic milking.

TV award featuring Teagasc research

New Decade TV won the TV category of the recent Guild of Agricultural Journalism Awards, sponsored by AIB, for 'How seaweed could be big business' featuring Dr Maria Hayes and Dr Ciaran Fitzgerald, Teagasc Food Research Centre, Ashtown. Teagasc's Catriona Boyle, Eric Donald and Dr Frank O'Mara worked with New Decade on content development for this series. Congratulations also to John Noonan and Mark Moore of Teagasc who won in the Best Technical category at the awards for their article 'Unique breed preservation'. Two articles from *TResearch* were also nominated for this category (Stuart Green for 'Mapping grass from space' and Sinead Waters *et al.* for 'Improving Feed Efficiency').

Cheese symposium

The ninth Cheese symposium, held in Cork in November, welcomed 190 international cheese scientists from 27 countries, comprising research providers and industry delegates.
Organised by Teagasc Food Research Centre, Moorepark in collaboration with University College Cork and INRA (L'Institut National De La Recherche Agronomique) France, it is now believed to be the second largest rolling cheese science conference held anywhere, globally. The symposium programme comprised 35 speakers representing 17 different countries, with a focus on seven main thematic areas: health and cheese; cheese quality and safety; cheese sensory and flavour chemistry; cheese processability and new analytical technologies; cheese structure – function relationships; and cheese market trends. Its objective was to provide a platform for cheese scientists from research providers, as well as from industry, to consider new concepts and latest developments, to share experiences and knowledge, and to promote new applications of cheese research.

Pictured at the ninth International Cheese Symposium are: Professor Paul Kindstedt, University of Vermont; Dr Patrick O'Riordan, Glanbia Foods; Professor Gerry Boyle, Director, Teagasc; and Dr Rani Govindasamy-Lucey, University of Wisconsin.

RESEARCH FUNDING

Teagasc receives grant awards worth €7.6m

Teagasc recently welcomed the grant awards for agri-food and forestry research, which were announced by the Minister for Agriculture, Food and the Marine, Simon Coveney. Teagasc is leading 18 of the 37 collaborative inter-institutional funded projects and is a collaborator in a further eight projects. In total, funding to Teagasc under these awards totals €7.6 million. Teagasc Director of Research, Dr Frank O'Mara, said Teagasc looks forward to starting the projects, which will underpin the future success of the Irish agri-food and forestry sectors. He particularly welcomed the close collaboration with other Irish research institutions and organisations, including UCD, UCC, UL, CUMH, Tyndall National Institute, CIT, ICBF, NUIG, NUIM, TCD, DIT, AFBI, CAFRE, St Angela's, GMIT, NICHE and LIT, which is fostered by these research funding programmes.
The project to create a Virtual Irish Centre for Crop Improvement, led by Dan Milbourne of the Crops Research Department, Oak Park, and involving UCD, NUIG, NUIM, and TCD, is particularly exciting. Total funding for this project comes to €2.99 million.
Dr Donagh Berry, Teagasc Animal and Bioscience Research, Moorepark, will lead two projects, with ICBF and UCD, on long-term sustainable breeding strategies for consistently superior health in cattle with a second project on multi-breed sheep genetic and genomic evaluations. These projects are valued at €1.12 million and €1.20 million, respectively.

Stimulus funding for bio-economy research

A multi-disciplinary research team, led by Teagasc, and including the Technology Centre for Biorefining and Bioenergy at NUI Galway, Crop Science and Biosystems Engineering at UCD and the Environmental Sustainability and Health Institute at Dublin Institute of Technology, has been funded by a 2014 Department of Agriculture Food and the Marine Stimulus research grant to address how Ireland can capitalise on the growing bio-economy. The European bio-economy employs some 21.5 million people and presents an annual market worth over €2 trillion, with significant potential for further growth, as EU member states supplement food production with sustainable technologies for production of biofuels, bio-fertilisers, bio-chemicals and bio-plastics.
Over a two-year period, starting in December 2014, this team will undertake research to assess Ireland's natural resources and core strengths, and match these to global market opportunities.

Strategic Research Proposals Group

Minister for Skills, Research and Innovation, Damien English T.D., recently launched the new Horizon 2020 Strategic Research Proposals Group, which will help identify large-scale EU funding opportunities for businesses and researchers in Ireland and to nurture applications for large-scale projects of strategic value to Ireland. The Group consists of a dedicated team of senior executives and officials from all research funding Government Departments and Agencies. Teagasc's representative in the group is Professor Gerry Boyle.

Food Harvest 2020's multiplier effect

An estimated 16,500 additional jobs will be created in the Irish economy if the targets of *Food Harvest 2020* (FH2020) are achieved, according to a recent paper in the *Irish Journal of Agricultural and Food Research*. The paper examines the job creation potential of the four main sectoral growth targets in the FH2020 development plan for Irish agriculture, namely milk, beef, sheep and pigs. Findings show that, as well as the direct employment that would be created from an increase in activity in the agriculture sector, there would be a knock-on benefit for the rest of the economy arising out of the linkages between agriculture and other economic sectors, as well as the spending of those additionally employed on goods and services produced in the economy. This is commonly described as the multiplier impact. The research also illustrated that economic analysis of the impact of the achievement of output targets such as those set out in the Food Harvest Committee report depends importantly on the nature of the relationship between growth in agricultural output and employment.

Journal of Dairy Science highlighted article

An article by Dr Emer Kennedy, Animal and Grassland Research and Innovation Centre, Teagasc, Moorepark, was selected by the *Journal of Dairy Science* as a highlighted article of the month by the editor-in-chief, Matt Lucy. The article, entitled: "Effect of feeding colostrum at different volumes and subsequent number of transition milk feeds on the serum immunoglobulin G concentration and health status of dairy calves" featured in the November issue of the *Journal of Dairy Science*. As a highlighted article, it featured prominently on the journal's home page for the month.

Best poster award

Patrick Forrestal of Teagasc Johnstown won the best poster presenter award at the recent technical meeting of the International Fertilizer Society for his poster 'Grassland Nitrogen Uptake and Use Efficiency as Affected by Fertiliser Nitrogen Source and Inhibitors'.
The poster presents the performance of a range of fertilizer N products including CAN, urea, and urea with inhibitors in grassland. This work forms part of a large Teagasc – Agri-Food and BioSciences Institute project conducted in 2013 and 2014 to develop resilient N management solutions to facilitate sustained or increased production while reducing emissions of the potent greenhouse gas nitrous oxide.

2014 Walsh Fellowship Awards

The Director of Teagasc, Professor Gerry Boyle, and the President of UCD, Professor Andrew J. Deeks, announced the award of nine new postgraduate fellowships to UCD being funded by Teagasc under its Walsh Fellowships Postgraduate Programme.

These nine new Fellows will join the existing 125 Fellows already being funded in UCD under the programme and undertaking a broad range of innovative research under the joint supervision of UCD and Teagasc staff.

It is expected that further Fellowships will be announced early in 2015 following the announcement by Minister for Agriculture, Food and the Marine, Simon Coveney of the success of joint UCD/Teagasc proposals under the Department of Agriculture, Food and the Marine's recent FIRM, Stimulus and CoFoRD programme calls. The new Fellows will undertake research across a range of areas in dairy, beef and pig production, climate change and the engagement of dairy farmers with the important issue of health and safety on farms. In addition to the nine new research-based Fellows, 10 new Walsh Fellows will join the UCD/Teagasc Masters in Agricultural Innovation Support Programme.

Teagasc and Glanbia's sustainable farm

Teagasc and Glanbia Ingredients Ireland have announced details of a new sustainable farm initiative at Kildalton College, the largest agricultural college in the country operated by Teagasc.

The Kildalton Open Source Sustainable Farm initiative will measure success across four key pillars with economic sustainability underpinning all four. These pillars are: resource-use efficiency – water, energy and nutrients; land management – to maintain and develop biodiversity; animal welfare; and, health and safety. Progress in each of these important areas will be benchmarked globally and measured against target on an annualised basis. The farm will be used to demonstrate best practices, which will ensure sustainable farming systems into the future.

Ag education increases farm income

There is a positive and significant economic return to formal agricultural education for Irish farmers and Irish society, according to Professor Gerry Boyle, Director of Teagasc. He was speaking at the launch of a new Teagasc research report 'The Economic Returns to Formal Agricultural Education' at the Teagasc College of Amenity Horticulture, National Botanic Gardens, Dublin.

Professor Boyle said that the study confirms a positive return to agricultural education in terms of the internal rate of return from a human capital perspective, and also the benefits from agricultural education to farm-level yields, intensity, and income. The study was based on Teagasc National Farm Survey data on 1,100 farms for the period 2000 to 2011.

The analysis shows that holding an agricultural education qualification increases family farm income. Professor Cathal O'Donoghue, Head of Teagasc's Rural Economy and Development Programme and co-author of the report, said that the actual pathways through which formal agricultural education increased income was by improving farm-level yields and intensity in terms of livestock units per hectare. Typically, average gross margins per hectare were between 1.3 and 1.7 times higher for those farmers who have formal agricultural education compared to those who do not.

Presenting information on the internal rate of return, Professor O'Donoghue confirmed that that private return to agricultural education was 8.8%, which is higher than the 5.8% return to higher tertiary education. In addition, the social return for agricultural education at 13.4% was higher than that for higher tertiary education at 5.7%. Incorporating the broader supply chain impact, Professor O'Donoghue outlined how the social returns from agricultural education reach over 24%.

American Society of Agronomy award

Teagasc Walsh Fellow Sara Vero was awarded second place in the Environmental Soil Physics and Hydrology Student Competition at the ASA-CSSA-SSSA annual international meeting in California, where she presented her PhD research on identifying the time lag in water-quality changes in response to programmes of measures.

Gateways to Dairy Process Innovation

Teagasc Food Research hosted an industry targeted Dairy Process Innovation event in Moorepark, as part of the Teagasc Gateways to Food Innovation series. The day focused specifically on current and next generation dairy processing and technology utilised by the dairy and infant formula industry. The event was a showcase of technologies for food enterprises and highlighted the research and development activities, at both Teagasc and University College Cork (as part of the UCC/Teagasc Strategic Alliance in Food Research), including expertise and services available to the sector.

Pictured at the Teagasc Gateways event on Dairy Process Innovation at Teagace Food Research Centre, Moorepark, are Dr Sinead McCarthy and Emily Crofton, Teagasc and Evie Flynn, FullFill Dairy. Photo O'Gorman Photography.

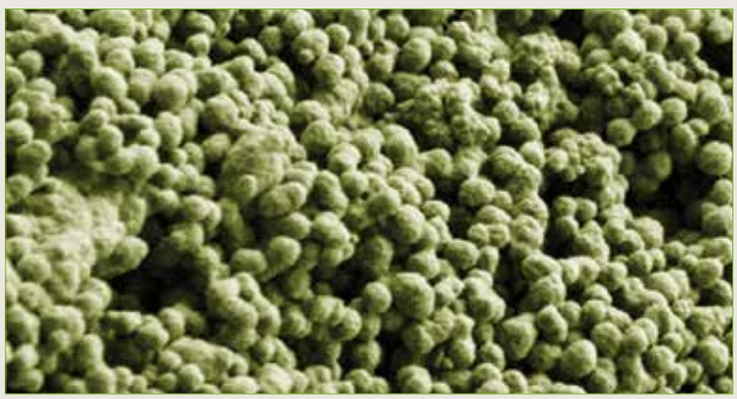
EI showcase

Pictured at the first national Enterprise Ireland Innovation Showcase in the Convention Centre, Dublin are Liana Drummond, Noel McCarthy and Ciara McDonagh from Teagasc Food Research Centres, Ashtown and Moorepark.

Soil photo competition

Walsh Fellow, Leanne Roche was recently awarded second place in the University of Reading 2014 Soil Photo Competition, for her photo of spring malting barley trials in the south east of Ireland. All winning photos can be viewed at: http://blogs.reading.ac.uk/soil-research-centre/

Novel enriched fat replacers



Dried calcium-enriched fat replacer particles 200 nm in diameter.

Following market research and industry engagement relating to a novel Teagasc patented technology, through a feasibility study, Teagasc is seeking food and beverage industry partners to assist with its development and commercialisation of the production of nano/micro-particles as protein-based fat replacers for food and beverage applications.

Summary

Teagasc researchers have developed and patented a novel platform technology ('kinetic trapping') to produce novel, protein-based, calcium-enriched fat replacers on a laboratory scale with encouraging results. The aim is to progress to larger scale trials and commercialisation, and input from industry will be critical at this point.

Value proposition

Produce high-quality, reduced-fat and low-fat foods – The demand for reduced-fat products is unlikely to decrease as obesity is a global concern with over 1.4 billion overweight and obese adults >20 years old worldwide (according to the World Health Organization). This platform technology has produced protein-based fat replacers that do not compromise taste and flavour and have the advantage of additional health benefits as they are naturally enriched with absorbable calcium and soluble dietary fibre.

The technology

This novel technology produces a calcium-enriched microparticulated whey protein (MWP) fat replacer through a process called 'kinetic trapping', which involves the natural separation tendencies of certain proteins and polysaccharides. This produces separated spherical calcium-enriched MWPs, in the size range 100nm to 5µm, dispersed in a konjac gum-rich solution.

Using careful process control, with basic liquid processing equipment, consistently-sized, high-quality, calcium-enriched fat replacers have been produced. The liquid can be used fresh or spray-dried and added as a weight-for-weight fat replacer to yogurt, low-fat spreads, mayonnaise and ice-cream products.

Preliminary informal sensory analysis indicated a creamy mouth feel to all resulting products, particularly ice-cream, with comparable sensory properties to current market leading fat replacers.

Compared to other MWP fat replacers on the market, our technology does not require extensive mechanical processes and is produced using simple liquid processing equipment, e.g. steam-jacketed vessels, low-pressure pumps and gentle paddle mixers.

Advantages

- Easily transferable technology to industry as it only requires basic and readily available liquid processing equipment.
- The size of the spherical particles produced can be controlled (from 100nm to 5µm), adding to product consistency.
- Use as a fat replacer to produce low fat and reduced fat foods and beverages.

Opportunity

Kinetic trapping is relevant to food and beverage companies interested in producing low-fat or reduced-fat foods to produce technologically advanced products.

Intellectual Property status

Teagasc PCT patent application published September 18, 2014. Application number: PCT/EP2014/054718, Available online: http://www.google.com/patents/WO2014140023A1?cl=en

Funding

This project was supported by Enterprise Ireland (reference: POC-2009-260 and CF-2013-0072-Y).

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Dr Eimear Gallagher, Senior Research Officer Teagasc, making dough with students from Colaiste Mhuire, Cabra.

Ciaran Arshad,
Research Operations,
Teagasc Head Office.

Science Week 2014

During Science Week 2014, Teagasc research centres invited local schools to meet its staff to learn about the work Teagasc does to support science-based innovation in the agri-food sector and the broader bioeconomy that will underpin profitability, competitiveness and sustainability.

Science Week is coordinated by SFI Discover, the education-outreach programme of Science Foundation Ireland.

"We are delighted to support the Science Week initiative, which aims to promote the relevance of science, technology, engineering and maths in our everyday lives and to demonstrate their importance to the future development of Irish society and to the economy," said Dr Frank O'Mara, Director of Research at Teagasc.

Visiting students at Teagasc Food Research Centre, Ashtown, Co Dublin, participated in a microbiology demonstration, which showed them how unclean hands can easily spread bacteria. They also had a chance to work the sausage-making machine, which they enjoyed enormously. One teacher expressed their students' enjoyment of the day: "I know the students had a great day. It has given them a great insight into Teagasc's work and it was brilliant that they got to see such a variety of projects."

Students visiting the Teagasc Animal and Grassland Research and Innovation Centre, Grange, Co Meath, got a taste of the work done in microbiology and genetics. Some volunteers had the opportunity to do some simple laboratory tests, as well as participate in the diagnosis of the mystery bacteria causing mastitis.

Teagasc Crops, Environment and Land Use Research Centre in Oak Park, Co Carlow had tours for students from Pearse College of Further Education, Dublin and Carlow Institute of Technology. They heard talks and demonstrations from the researchers working on potato breeding, plant technology, bioenergy crops and GM potato trials. The groups engaged in good discussions with the researchers and some interesting debates occurred during the day about the science behind the topics, and what the future has in store for the respective industries.

Students who visited Teagasc Moorepark Research Centre in Co Cork had the opportunity to meet current

Dr Karen Daly, Teagasc, Johnstown Castle, talking to students from Meánscoil Gharman about soil sampling and nutrient processes at the centre's Science Week Ireland event.

Eureka Secondary student Laura Keogan trying her hand at an experiment at Teagasc Research Centre, Grange, during Science Week with geneticist Dr Emma Finlay.

Pictured on a visit to the Teagasc Moorepark Dairy Research Centre during Science Week are pupils from Loreto Secondary School, Fermoy, Shauna Chan and Sarah Casey; with Justine Deming, Teagasc Walsh Fellow.

PhD and Masters students who showed them the facilities and provided an insight into their studies. Visiting students also had the opportunity to feed calves and learn about grassland management, breeding and genetics.

The Teagasc Crops, Environment, and Land Use Research Centre at Johnstown Castle, Co Wexford welcomed students from a local Gaelscoil to its facility and had some of its seminars and field visits 'as Gaeilge'. Students learned about current Teagasc research in the areas of ecology, carbon cycling, water quality and soils, nutrient efficiency and sustainability. Daire O'Huallachain, Research Officer at Johnstown Castle, expressed the importance of encouraging today's youth into this field of work: "Tá sé go hiontach go bhfuair micléinn Meanscoil Gharman blás ar an cinéal taighde timpeallachta atá ar siúl againn i dTeagasc. Tá sé tabhachtach an chéad ghlúin eile a spreagadh chun suim a léiriú san eolaíocht."

Teagasc Advisory Office in Ballymote, Co Sligo, hosted visiting students from the surrounding area. Students got a detailed explanation about the role of Teagasc, the Green Cert and other courses and careers in agriculture.

Smart Futures

Smart Futures is a Government-industry programme providing science, technology, engineering and maths (STEM) careers information to second-level students, parents, teachers and career guidance counsellors in Ireland.

Dr Kieran Jordan, Teagasc Food Research Centre, Moorepark, spoke at Athlone IT and Dr Ríona Sayers, Research Officer, Animal Health, Teagasc, Moorepark, spoke at the University of Limerick. Both speakers talked through their own career stories, from what they studied in school, to what they did at third level and beyond. The objective of these talks was to show current students that that they were also teenagers once, trying to make choices about what to do next.

"The aim of Smart Futures is to grow student awareness of STEM (Science, Technology, Engineering and Maths) careers and positively impact on the retention of STEM subjects for Senior Cycle, as well as to improve their perceptions of what kind of people work in STEM roles in Ireland, so they might see them as viable and attractive potential career paths. The roadshows were very well received by teachers and students, who had the chance to ask practical questions and get insights from real people working in science and engineering, to see what skills they have developed and how they are used in their roles. We were delighted to have some fantastic Teagasc researchers engaging students in this way," said Donna McCabe, Smart Futures Programme Coordinator, SFI.

A big deal: Three phrases that created a new climate for European agriculture

Changes made at a recent meeting of European prime ministers mean a new direction for policy on climate change.

Dr Rogier Schulte, Teagasc, Leader in Translational Research on Sustainable Food Production
Trevor Donnellan, Principal Research Officer, Rural Economy and Development Programme, Teagasc
Dr Gary Lanigan, Principal Research Officer, Crops, Environmental and Land Use Programme Teagasc
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Last October, we witnessed a fundamental shift in the debate on agriculture and climate change. Europe's prime ministers gathered in Brussels to agree a 15-year plan to tackle climate change. Most observers and journalists on the night would have reported the headline figures that the European Council had just signed up to:

- reduce EU greenhouse gas emissions by 40%;
- increase EU energy efficiency by 27%; and
- increase the share of renewable energy in the EU to 27%.

But for anyone involved in agriculture, it was another part of the agreement that drew most attention. Three well-crafted phrases in 'paragraph 2.14', proposed by Ireland and now accepted by Europe, have created a new policy climate for European agriculture. This new agreement recognises that agriculture is not simply another 'polluting industry'. Instead, it also has positive effects on the climate.

What was at stake?

The stakes were high. There was an element of déjà vu, reflecting the atmosphere of previous climate talks in 2008, when Ireland was given the task of reducing national emissions by 20% by 2020; no other country was given a tougher target at the time.

Ireland's Taoiseach, Enda Kenny, met with his European colleagues to agree Europe's targets for 2030. In a worst-case scenario these targets would simply have been tightened further. For Ireland, more than any other EU Member State, this would have had drastic consequences for agriculture. Our agricultural sector accounts for about a third of national greenhouse gas emissions. By contrast, agriculture accounts for only 10% in most other European countries, which is largely due to the heavy industries that 'dilute' their farm emissions. But, in Ireland, it is not possible to subscribe to large reductions in our national greenhouse gas emissions without also reducing emissions from farming. Therefore, the worst-case scenario could have resulted in the introduction of 'carbon quota' for agriculture.

What would that have meant for Irish farming?

In Ireland, we have had this debate on carbon quota, and we know that it would give us and Europe the worst of both worlds. Not only would it curtail agricultural production, it could also increase global greenhouse gas emissions. Scientific research has shown that the carbon footprint of Irish food is amongst the lowest in Europe and indeed the world. We know that the global demand for food will continue to rise. In particular, burgeoning middle classes in Asia are predicted to demand ever more meat and dairy produce. If our efficient farmers are not allowed to produce more food in Ireland for this growing appetite, then less efficient farmers will do so elsewhere. The end result of carbon quota: less food, more greenhouse gases, more climate change.

What can we do?

Quite a lot, actually. We can tackle the twin challenges of food security and climate change through efficiency. Using simple steps, such as a longer grazing season, more productive animals, and even nutrient management planning, we can reduce the 'carbon footprint' of our produce. This is the amount of gas we produce per litre of milk, or per kilogram of meat. Recent Teagasc research shows that Irish farmers have already been on this journey for quite a while; in 2013, each meal of Irish food produced 15% less greenhouse gas than the same meal in 1990.

And this trend need not stop this year; if we continue to reduce our carbon footprint, then it is possible to grow agriculture in line with Food Harvest 2020, while at the same time 'flat-lining' greenhouse gas emissions. And that is good news. The better news is that all the actions that reduce the carbon footprint also reduce costs on the farm. And that is not just a theory. Last year, the Teagasc National Farm Survey showed that the most profitable dairy farms were also the farms with the lowest carbon footprint.

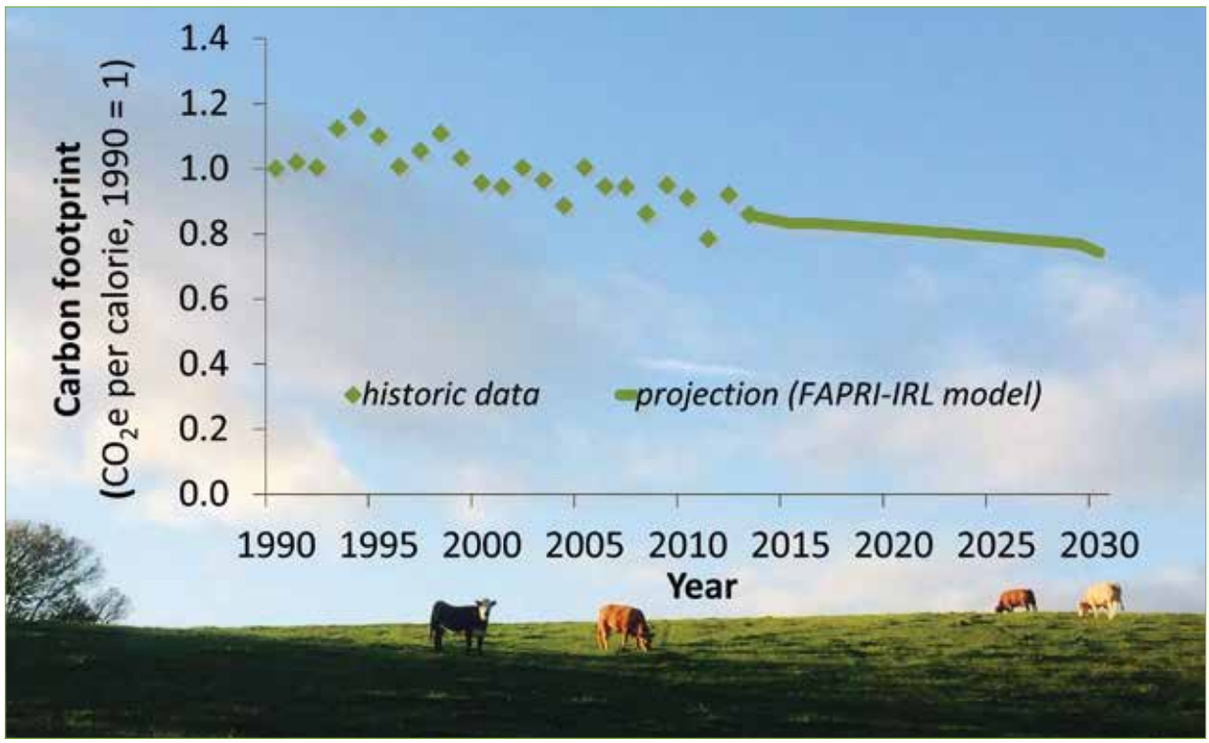

Figure 1. Carbon footprint of Irish produce compared to 1990 (CO_2-equivalents per calorie, 1990 = 1).

Only half the story

And of course we know that farming does not only emit greenhouse gases to the atmosphere, it also takes carbon dioxide from the air and locks it up in the ground. This storage of carbon (called sequestration) is particularly effective in permanent grasslands and forestry. It needs no explanation that the potential for this sequestration in Ireland is promising, to say the least. But for reasons that are not entirely clear to anyone, European climate policies have thus far not allowed for these positive effects of agriculture to be counted. Therefore, under the current policies there has been no incentive for efforts to foster these positive actions, as there has literally been no credit given for them.

A new climate

Three sentences changed this at the recent meeting of ministers. The clause proposed by Ireland ensures that Food Security concerns are on an equal footing with Climate Change. In practice, that means that blunt instruments that reduce emissions at the expense of food production are off the table. In the second sentence, Europe commits to look into a different way of dealing with agriculture, one that recognises not only the negative, but also the positive impacts that farming has on the climate. The final sentence simply buys time: the details of such an alternative approach are yet to be worked out.

These changes have been won on the basis of sound science, rather than hearsay or sound-bites, by a broad task force that was led by the Department of Agriculture, Food and the Marine and that included experts from Teagasc, the Environmental Protection Agency and Bord Bia. The end result was three sentences that created a milder climate for European agriculture. This does not mean that farming can disengage from the global climate question. Indeed, many challenges remain. Individual country targets have yet to be allocated and it is unlikely that Ireland's 2030 target will be less onerous than our 2020 target. But, in the new policy climate, credit will be given where credit is due. Specifically, we will be allowed to address our targets by storing more carbon in the soil, for example through incentives for afforestation.

What's next?

The details of the new agreement are yet to be worked out, but there is not a lot of time. In December 2015, the focus turns to Paris, where all the countries of the United National Framework Convention on Climate Change (UNFCCC) will meet to hammer out a global plan to combat climate change after 2020. Next year's meeting is particularly vital, as the world needs to agree what it will do after the current Kyoto Protocol expires in 2020. Traditionally, the EU has played a lead role in the global negotiations. This gives even more importance the agreement. 'Paragraph 2.14' is the approach to agriculture that the EU will now be proposing to the world next year.

The scientific input by Teagasc into this process was led by the Working Group on Greenhouse Gas Emissions.

Follow Rogier Schulte on Twitter at @RogierSchulte

The Agricultural Catchments Programme - A policy perspective

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Teagasc's Agricultural Catchments Programme (ACP) is a national research programme funded by the Department of Agriculture, Food and the Marine (DAFM). It is recognised internationally as a benchmark of good scientific practice for providing comprehensive data necessary to evaluate agri-environmental policies. Dr Patricia Torpey and Dr Deirdre Fay, DAFM, explain how the ACP findings inform Government policies on sustainable intensification.

The ACP is Europe's most ambitious Catchments Science Programme. It was initiated in 2008 to monitor the effectiveness of Ireland's National Action Programme for the Nitrates Directive. After six years of intensive monitoring, the first results of the ACP indicate a positive response to Ireland's Nitrates Regulations, i.e., reduced nutrient inputs, increased nutrient management and some evidence of reduced nutrient losses from farmland to water. As a result, water quality trends are showing signs of recovery – although this is affected by time lags between the implementation of measures and measureable improvements in water quality.

Scientific knowledge generated by the ACP helps fulfil Ireland's monitoring and reporting requirements under the Nitrates Directive, including the Nitrates Derogation, and the Water Framework Directive (WFD), and provides the basis for technology transfer to stakeholders. These findings verify that Irish farmers are producing milk, meat and crops in an environmentally and economically sustainable manner. This scientific verification, in turn, bolsters Ireland's green credentials in the context of anticipated environmental pressures under Food Harvest 2020, the industry-led strategy, supported by Government, for growth of the agricultural sector.

Phosphorus source pressure is reducing

Phosphorus (P) loss to water is a cause of freshwater eutrophication and the Nitrates Regulations limit P use. Much of the ACP dairy catchment in Cork is being farmed under Nitrates Derogation with stocking rates in excess of 170kg organic nitrogen (N) per hectare.

The P source pressure in this catchment is reducing in terms of: declining farm-gate P balances; higher P use efficiencies; no recorded P application during the closed period; and decreasing proportions of Index 4 soils, which have soil P concentrations in excess of the agronomic optimum of Index 3, and which are associated with higher risks of P loss to water.

Importantly, these improvements were achieved while maintaining production comparable to the top 10% of specialist dairy farmers nationally. Results highlight potential for improved management by matching P applications to requirements based on field-scale soil testing. Potential policy tools available to close this gap include the promotion of soil testing through advisory programmes or regulation.

Understanding nutrient loss pathways improves targeting of measures

Improved targeting, and therefore cost-effectiveness, of agricultural measures is an important element of the EU's Common Agricultural Policy. The ACP is providing new insight into the pathways of nutrient loss from agricultural landscapes, allowing the identification of risk areas where measures can be targeted with a higher degree of likelihood that they will be effective.

For example, well-drained and poorly-drained soils behave differently in the transfer of nutrients from land to water. The ACP has found that while surface flow pathways dominate P loss in poorly-drained catchments and below-ground N loss dominates in well-drained catchments, there are substantial below-ground P losses in well-drained catchments and N losses via ditches in poorly-drained catchments. Thus, measures directed at specific areas of overland flow generation may be more effective when targeted in catchments with poorly-drained soils.

Drainage ditches feature in poorly-drained land and their characteristics can significantly influence the retention or transfer of P from upstream sources to downstream areas. Innovative ACP work, relevant to potential policy options such as buffer strips and wetlands, offers an opportunity to exploit existing ditch networks using techniques to minimise nutrient losses.

Karst catchments can effectively buffer nutrient losses

Groundwater bodies underlain by karst were assigned poor status in the first WFD cycle. In a karst catchment (zone of contribution) in Mayo, the ACP has found that water quality is good, despite being farmed intensively and having a high proportion of soil P index 4 fields (considered to be agronomically and environmentally excessive). The karst zone effectively buffered nutrient losses and furthermore a groundwater vulnerability map specific to P developed by the ACP showed that just 2% of the entire area posed a potentially high risk of P loss to groundwater. These new findings will contribute to improved targeting of measures and to updating groundwater body status in the second WFD cycle due to commence in 2015.

Scientific evidence of lake recovery following Nitrates Regulations

The ACP investigated the impacts of diffuse nutrient loss over the last 150 years on a Monaghan lake. Analyses of lake-bed sediment cores showed the lake becoming eutrophic by the 1960s following increasing agricultural intensification. However, since the 1990s, and particularly post-2000, evidence suggested a decrease in pollution of the lake despite continued increases in agricultural intensification. This positive change in water quality is attributed to decreasing nutrient losses from the catchment arising from a combination of agri-environmental schemes and the Nitrates Regulations. More recent work shows that climate pressures, especially increased summer storms, can complicate this recovery.

Closed spreading period is effective

Scientific monitoring by the ACP has shown that the closed spreading period is effective in reducing nutrient losses from agriculture to water – an objective of the Nitrates Directive. Comparisons between two grassland and two arable catchments indicated that, while the closed period accounted for just 25% of the year, up to 57% of annual N loss and up to 40% of annual P loss occurred during this time. The annual nutrient loads being lost were low to moderate when compared with international studies. However, if slurry spreading was permitted to be carried out during closed periods, the potential for further N and P losses would be high. This is due to the coincidence of high rainfall and poor nutrient uptake by plants, during the winter months.

Sustainability indicators

Uniquely, the ACP integrates bio-physical with socio-economic processes to evaluate the impacts of the Nitrates Regulations. Sustainability indicators based on farm-gate nutrient balances and nutrient-use efficiencies are being developed using National Farm Survey data and these will be tracked over time for the most intensive specialist dairy farm systems. This work will provide valuable information to evaluate Food Harvest 2020 and milk quota abolition impacts.

Understanding farmers' attitudes helps allocate knowledge transfer resources

Four main opinion groups of farmers were identified during a baseline survey of ACP farmers. In general, two of these groups were unconvinced regarding the appropriateness of certain measures in the Nitrates Regulations, while the remaining two opinion groups were either positive about, or unaffected by the Regulations.

In terms of targeted advice (and agri-environmental schemes), the challenge will be to engage in a more meaningful discussion with those groups who have concerns about the Nitrates Regulations, especially as these farmers are the most likely to embrace the objectives of Food Harvest 2020.

Benefits to policy

Teagasc's ACP is an important research project and the findings arising from it will contribute to informing the Nitrates Review in 2017, and to further enhancing the accuracy and effectiveness of the Nitrates Regulations. The programme will also provide insight into the contribution that Irish farmers are making to the delivery of WFD objectives. The research findings of the ACP will also cohesively contribute to closing the scientific verification gap identified in the Milestones for Success 2014 report, through sustained and intensive monitoring of the interface between agri-economic growth and agri-environmental sustainability. Improved knowledge transfer and improved policy integration will be important in communicating these research findings, and is crucial in order to effectively increase the use of this scientific-based knowledge to influence the uptake of best management practices by farmers.

New cheese: The product of an innovative collaboration

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A collaborative development project between Teagasc, the Irish Dairy Board (IDB) and Tipperary Co-operative Creamery Ltd resulted in the recent launch to market of Kildery cheese in Germany.

In 2011, Teagasc and the IDB announced the creation of a new Dairy Innovation Centre based in Moorepark, Co Cork. It was established to develop market-led product concepts that can be manufactured by IDB members, which would be then marketed internationally by the IDB. The underpinning concept of the Dairy Innovation Centre was to draw on the capability of the Teagasc Food Research Centre, Moorepark, to provide key scientific and technological advances, particularly in the areas of dairy chemistry and technology, through its dedicated research staff and research programmes; and to combine this with the IDB's ability to identify market opportunities, to harness consumer insights to drive innovation, and the IDB's considerable market and distribution infrastructure and global reach. Complementary to these capabilities would be the partnerships of individual IDB members, such as Tipperary Co-operative Creamery Ltd, which would provide the production capabilities, as well as its technical experience, to facilitate the conversion of new concepts into commercial products and would undertake manufacturing on a commercial basis.

Kildery cheese launched on German market

In June 2014, a major output of this programme, Kildery cheese was launched to market in Germany to be sold under the prestigious Kerrygold brand. Kildery was developed at the Teagasc Food Research Centre, Moorepark, in collaboration with Tipperary Co-operative Creamery Ltd. and the IDB. Kildery may be broadly considered to be a Maasdammer-style cheese with its associated large, round lustrous eyes, but Kildery is differentiated in part, by its more intense and mature flavour, in contrast to conventional Maasdammer-style cheeses. The cheese has already achieved success, winning the 2013 silver medal in the Continental cheese category at the global cheese awards, prior to its commercial launch, and this was followed up by winning the 2014 gold medal in the same category just after its launch to market. Manuel Rodriguez-Eicke, marketing director of Kerrygold in Germany, says: "Kerrygold Kildery cheese complements our existing range of Kerrygold Cheddars and Butterkase cheeses and brings Kerrygold into the Maasdam category, which is the largest branded cheese category in Germany. The launch of Kildery cheese in 2014 will move Kerrygold from being a specialty cheese player to a mainstream cheese brand in the German market." Such success increases the potential for launch of this award-winning new product into other markets over the coming years.

Teagasc cheese development programme

"Technically a challenging cheese type, its development was made possible through the expertise within the cheese diversification research programme at the Teagasc Food Research Centre, Moorepark," suggests Dr Diarmuid Sheehan, Cheese Programme Manager for the Dairy Innovation Centre. Traditionally, the Irish cheese industry has been heavily focused on Cheddar production (accounting for about 80% of cheese production); however, such markets have been predicted to grow more slowly than other semi-soft and semi-hard cheese types. The cheese diversification research programme was set up within Teagasc to diversify the national cheese portfolio through:

- Research focused on – manipulation of specific cheese physico-chemical, biochemical, and microbiological parameters under changing processing conditions to develop a range of cheeses with diverse characteristics, flavours and functionalities, but which are capable of being manufactured in existing commercial cheese production plants.
- Research investigating the influence of localised variations within the cheese matrix microstructure on the physiological state and metabolic activity of cheese bacterial microflora during ripening. This encompasses the development of new microscopic techniques to determine compositional and physicochemical variability and the application of Flow Cell Cytometry techniques to elucidate bacterial physiological state and metabolic activities, with the overall objective of achieving optimised consistency in Irish export cheeses, as well as facilitating greater diversification.
- Application of DNA-based approaches – such as next-generation sequencing technologies – to profile both dominant and sub-dominant microbial species within Irish cheeses. Such methods facilitate the detection of both specific microbial populations and of encoded metabolic pathways and are being utilised to enhance the quality and consistency of Irish commercial cheeses.
- A strong industry interactive programme engaged in supporting developments in eye-type continental cheeses, hard Mediterranean-type cheeses and in novel Cheddar variants.

Pilot scale to commercial scale

Development of Kildery began with the creation and trialling of cheese-making processes by technologists using the Moorepark Technology Ltd pilot plant facility. Further progress was achieved through iterative developments of initial prototypes by applying scientific principles and in-house expertise generated through ongoing cheese research programmes. This resulted in the development and refinement of prototypes, which underwent technology transfer to commercial scale. In commercial scale trials, technologists from Teagasc, the IDB and Tipperary Co-op combined their diverse areas of expertise to optimise the production and ripening processes resulting in Kildery cheese.

Overall, the application of scientific and technological advances and expertise developed through the Teagasc cheese diversification programme, the capacity of the IDB to identify market opportunities and utilise its market distribution infrastructure, combined with the production expertise and technical capabilities of Tipperary Co-op, have resulted in a successful launch in a key export market

"As we approach the end of the milk quota system, this project highlights the strength of the collaborative approach taken between Teagasc, Tipperary Co-op and the IDB. It has enabled us to expand our continental cheese portfolio to meet a key market requirement," outlined Mr John Hunter, Assistant General Manager, Tipperary Co-op.

The importance of cheese with removal of milk quotas

Abolition of milk quotas in 2015 is projected to result in a 2.75 billion litre increase in milk production by 2020, equivalent to an increase of approximately 50%. This is expected to enhance the value of primary production by about €700 million, along with further downstream benefits in the form of increased dairy products, export earnings and employment (Food Harvest 2020 – the industry-led strategy, supported by Government, for growth of the agricultural sector). However, it also poses significant challenges in processing of this milk pool and in leveraging greater share of existing dairy markets and, crucially, in the development of new products to avail of new market opportunities.

Cheese has been targeted as a vital end-product for this increased milk pool due to continued increases in global cheese consumption, high end-use versatility, potential for significant added value, and as a profitable outlet for surplus milk fat. Surprisingly, cheese has not historically been a major component of the Irish dairy product mix and its share in milk utilisation has always lagged well behind that of European competitors. However, this is fast changing as evidenced by the growth in cheese production from 80,000 tonnes in 1995 to ~ 185,000 tonnes in recent years and there is potential for further growth up to 2020. Crucially, it is an export-led industry with approximately 93% of production exported annually.

Acknowledgements

The underpinning cheese diversification research programme has been funded by the Department of Agriculture, Food and the Marine's Food Institute Research Measure; the Dairy Levy Trust; and Teagasc Core funding.

A gut feeling about whey

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Whey protein intake has been shown to reduce food intake and body weight gain. However, the underlying mechanism for these effects was unknown. This article provides an overview of recently published data showing that whey protein intake dramatically alters the gastrointestinal tract, such that it appears to restrict the amount of food that could be consumed and, hence, weight gain. These data will help to establish health claims for whey-enriched food products.

The prevalence of obesity is growing worldwide. In Ireland, approximately 39% of Irish adults were overweight and 18% obese in 2005 (National Task Force on Obesity). The economic cost of obesity was estimated to be €4 billion, arising from the management of obesity and related health complications such as diabetes and kidney disease. The recently completed National Research Prioritisation Exercise further highlighted the importance of tackling the obesity problem by discovering "new bioactive components from natural resources, functional ingredients and nutraceuticals" and by undertaking "robust scientific research to underpin health claims".

What causes obesity?

The food that we consume provides the energy for maintaining bodily functions at rest and during physical activity. When food (energy) intake exceeds energy expenditure, excess energy becomes stored as fat in the adipose tissue, which causes the gain in weight. Because the adipose tissue has a limited capacity to store fat, a sustained positive energy balance leads to fat storage in other tissues such as the muscle, liver and the brain. This induces inflammation, reducing tissue functions, such as insulin sensitivity, leading to development of clinical conditions such as diabetes and kidney disease. Thus, there is an increasing interest to develop interventions that could reduce energy intake and/or increase energy expenditure, and thereby tilt the energy balance in favour of a weight reduction.

The gastrointestinal tract is a potential target for anti-obesity related interventions because this tissue plays an important role in nutrient digestion and absorption. In addition, the gastrointestinal tract also has the ability to control food intake. For instance, distension of the stomach as it fills with food stimulates the brain to limit further intake of food. Thus, interventions that could reduce the size of the stomach and/or shortened the intestinal length would undoubtedly limit the amount of food that can be ingested and subsequently absorbed through the intestine, leading to reduced weight gain. Bariatric surgery achieves this effect and is currently the only long-term solution to the obesity problem.

The mechanism for whey protein effects

Whey is a by-product of cheese manufacture. It is a rich source of proteins including lactoferrin and bovine serum albumin. Whey protein intake has been shown to reduce energy intake in humans. However, the underlying mechanism for these effects was unknown.

We recently showed that mice, fed whey proteins, had altered gastrointestinal expression of *Wnt* genes important for organ development compared to casein-fed controls (see Figure 1). This was accompanied by a reduction in the stomach weight and intestinal length (and weight). Whey protein intake also reduced energy intake and body weight gain (McAllen *et al.*, in press). Increasing the protein quantity (and proportionally reducing the carbohydrate content) in the diet dramatically reduced weight gain and the composition of

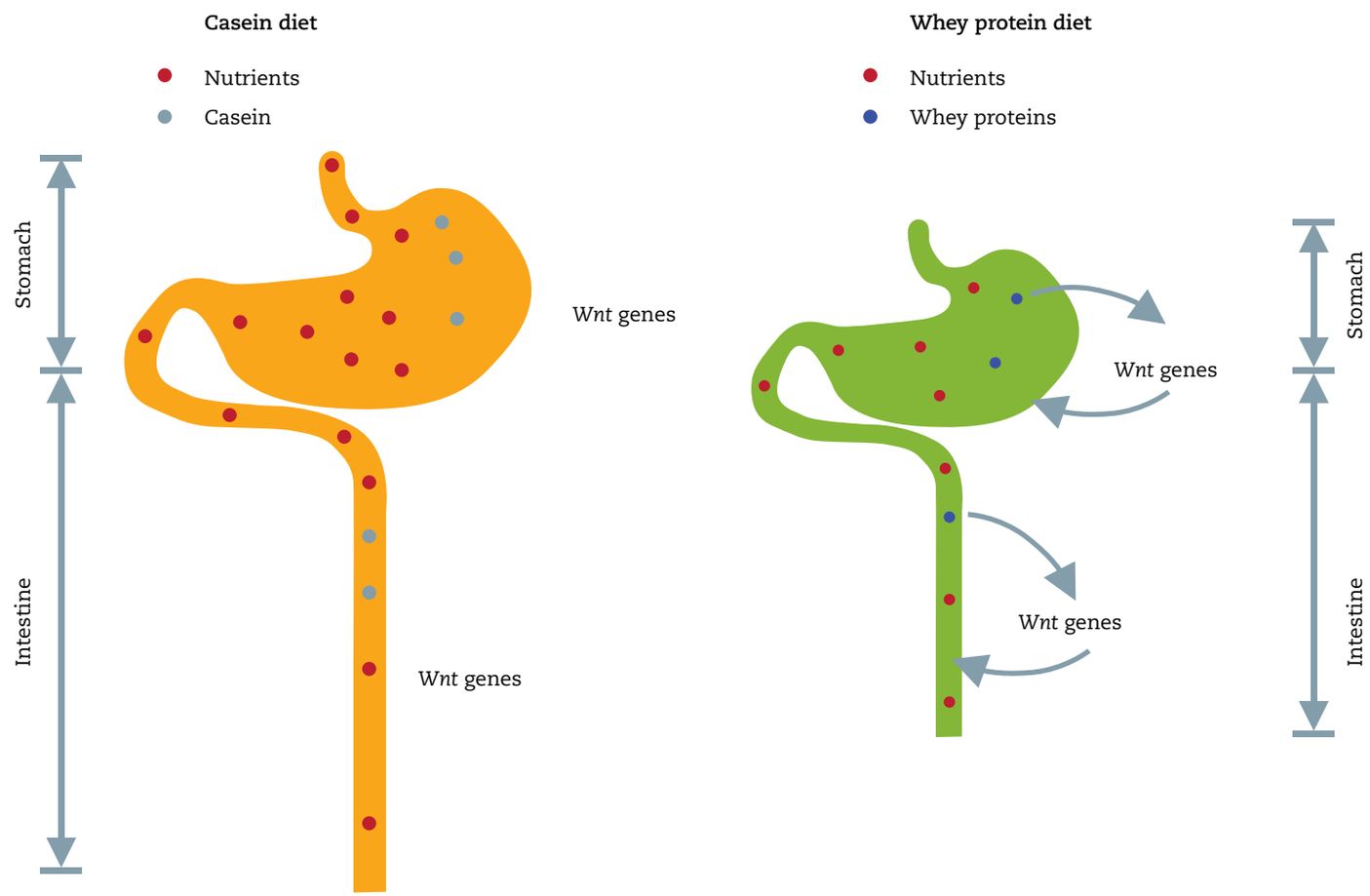

Figure 1: A mechanism by which whey proteins affect food intake and body weight gain. Whey protein intake alters the gastrointestinal expression of *Wnt* genes, leading to a reduction in stomach size and intestinal length. This reduces the amount of food that can be consumed and hence the gain in weight compared with casein intake.

microbiota inhabiting the gastro-intestinal tract (McAllen *et al.*, 2014; McAllen *et al.*, 2013). The data suggest a specific effect of whey proteins on *Wnt* gene expression, which could underlie how the proteins altered the gastrointestinal structure and in turn, the amount of food that could be consumed and absorbed through the intestine (Figure 1).

Relevance to policy makers and industry

With the abolition of milk quotas in 2015, the Irish industry has the opportunity to expand their product range developed for the health and wellbeing markets globally. Because whey is a by-product of cheese manufacture, there is a considerable economic benefit to utilising this nutrient as a health-promoting food ingredient. Our data show how whey protein intake could alter the gastroIntestinal tract and thereby the amount of food that could be consumed to gain weight. This information can be used to establish health claims for whey protein-enriched food products marketed to affected consumers.

Acknowledgements

This work was supported by the Teagasc Core Funding (Vision Programme on Obesity) and by the Teagasc Walsh Fellowship programme and was conducted in collaboration with Dr Paul Cotter (Teagasc), Professor John F. Cryan (University College Cork), Professor John R. Speakman (Chinese Academy of Sciences, Beijing, China), Professor Helen Roche (University College Dublin) and Professor Riitta Korpela (University of Helsinki, Finland). Teagasc Walsh Fellows PhD candidates associated with this project were: Dr Liam McAllan and Peter Skuse.

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Understanding *Campylobacter* - the €2.4 billion bug

‘Freeze your chicken to avoid food poisoning: Official watchdog’s cookery advice over bug that hits 500,000 Britons a year and kills 100’ (front-page headline, *Daily Mail*, 18 November). The ‘bug’ referred to is *Campylobacter*. One week later the Food Standards Agency (FSA, UK) reported that up to 78% of chickens were contaminated with this bacteria. Although relatively unknown to consumers, *Campylobacter* is the most common cause of food-borne illness in developed countries, including Ireland. It has the potential to cause reputational damage to the Irish food industry if control of its spread is not prioritised, explains Dr Declan Bolton.

There are an estimated 9.2 million cases of campylobacteriosis in the EU every year, costing the European economy €2.4 billion. The corresponding figures for Ireland are 100,000 cases and €25 million, although many professionals consider this to be an underestimate. Symptoms include diarrhoea, abdominal pain, malaise, fever, nausea and vomiting but approximately 1% of cases develop Guillain-Barré syndrome, a chronic and potentially fatal illness where the body’s immune system attacks part of the peripheral nervous system causing mild paralysis.

Most cases are associated with the preparation and consumption of poultry, although contaminated water (usually with bovine and/or ovine faeces) is also a major source. Many broiler flocks are infected with *Campylobacter* by the third or fourth week of rearing. These bacteria colonise the ceca and are subsequently shed into the production environment at concentrations of up to 10 million cells per gram of faeces, facilitating rapid spread throughout the flock. The only comprehensive surveillance study undertaken to assess the prevalence of *Campylobacter* was conducted throughout Europe in 2008. Ireland was bottom of the league table with 83.1% of broiler batches and 98.3% of carcasses contaminated.

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Genetically clever foe

Despite over 30 years of research, it is still unclear as to how an apparently fragile organism can cause so much misery and financial cost. More recently, whole genome sequence analysis and mutation studies have begun to reveal a complex and genetically clever foe. While flagellar-mediated motility encoded by the *fla*, *fli*, *flg* gene series has long been observed, recent research has discovered ‘chemotaxis’, the ability to sense the current environment and move towards more favourable conditions. *Campylobacter jejuni* put this attribute, encoded by the *che* genes, to good use during the invasion of poultry. By honing in on the mucins and glycoproteins in mucus they locate and move to the ceca, the most favourable site for survival and rapid multiplication in poultry.

This illustration depicts a three-dimensional (3D) computer-generated image of a cluster of drug-resistant *Campylobacter* bacteria, which were arranged in a mass of curly-cue shaped organisms. The artistic recreation was based upon scanning electron micrographic imagery. Image courtesy of Melissa Brower, Centers for Disease Control, USA.

Transmission to humans

Human infection requires adhesion to and invasion of target gastrointestinal cells. This process starts when an outer membrane protein on the *Campylobacter* cells, called CadF, binds to fibronectin, a glycoprotein found in human gastrointestinal epithelial cells. Through a complex series of interactions involving the protein products of several genes including *capA*, *pldA*, *jlpA*, *peb*1-4, *flpA* and *virB11*, *Campylobacter* binds tightly to the human cell and invasion commences. During invasion, the flagellum serves a secondary function (in addition to motility) as a secretion system, injecting a series of invading proteins into the host cell. The exact function of many of these invading proteins, encoded by the *cia*, *iam* and the *hrt* genes is unknown. However, it is thought that the *vikK* gene product protects against antimicrobial proteins while the FspA protein has a role in killing the human cell.

Campylobacter employ a range of defence mechanisms to avoid attack by our immune system. These include surrounding their cells in a polysaccharide capsule encoded by the *ksp* genes. Moreover, they employ a glycosylation system, encoded by the *pgl* multigene locus that modifies over 60 periplasmic proteins, deflecting antibodies. The exact role of lipooligosaccharides (LOS) in immune system evasion is poorly understood. These *Campylobacter* cell surface structures act as a self-defence mechanism for the bacteria but ironically are responsible for triggering the immune response that underpins Guillain-Barré syndrome. *Campylobacter* are also resistant to several antimicrobials including antibiotics, bile salts and heavy metals, often mediated by the *Campylobacter* multidrug efflux pump (CME). CME consists of a periplasmic protein (CmeA), an inner membrane efflux transporter (CmeB) and an outer membrane protein (CmeC), encoded by the *cmeABC* operon, expression of which is modulated by CmeR, a transcriptional repressor.

Campylobacter produce several different cytotoxins of which only the cytolethal distending toxin (CDT) has been studied in detail. CDT is a tripartite toxin composed of three subunits encoded by *cdt*A, B and C, respectively. The *cdt*A and *cdt*C gene products are responsible for toxin binding to the cell membrane, while CDTB enters the cell and blocks cell growth. As a result the host cell distends, the nucleus fragments and the cell dies.

Teagasc *Campylobacter* research

Teagasc has an ongoing programme of research on *Campylobacter* including identifying and trying to better understand the interaction between the various virulence factors that are responsible for human illness. Recent discoveries include the presence of different secretion systems in different *Campylobacter* species, the absence of chemotaxis genes in species other than *Campylobacter jejuni* and motility in the absence of the *flaB* gene. In collaboration with Dr Paul Whyte's laboratory in the School of Veterinary Medicine, University College Dublin and the Food Safety Authority of Ireland (FSAI), Teagasc also works in the areas of control on broiler farms and the development of novel processing technologies to eliminate these pathogens on poultry carcasses. To date, this work has delivered a combination (trisodium phosphate, capric acid and ultrasonication) processing technology that kills over 10,000 *Campylobacter* cells per cm^2 on broiler carcasses. Moreover, a novel approach to biosecurity recently achieved a *Campylobacter*-negative batch of 150 birds despite being surrounded by a positive flock.

Current *Campylobacter* contamination rates in Irish poultry are unacceptable, as are the high rates of human infection. The forthcoming EC microbiological criteria for *Campylobacter* for poultry carcasses will provide a new context and challenge for our poultry industry. New discoveries are providing an insight into the genetic coding underpinning the survival and infection mechanisms in this organism and should provide the basis for science-based solutions to protect public health and the international reputation of the Irish food industry.

Acknowledgements

The Teagasc *Campylobacter* research programme is funded by the Department of Agriculture, Food and the Marine (DAFM) through the FIRM programme and by Teagasc core funding. *Safe*food fund the *Campylobacter* knowledge network on the island of Ireland (http://safefood.ning.com/group/camplyobacter), providing an important dissemination tool and discussion forum informing our R&D activities.

Photo: Peter Murphy.

Food assurance and animal welfare in meat abattoirs

Management of animal welfare is not only a legal requirement; it has an impact on meat safety and quality. Kevin Brennan explains.

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The new animal welfare regulations 1099/2009 (S.I. 292/2013), which enact European Union (Protection of Animals at the Time of Killing) Regulations 2013, put in place a series of measures aimed at avoiding pain and minimising suffering and distress during the slaughtering process. The regulation places strong emphasis on well-trained and skilled abattoir operatives where personnel carrying out certain slaughter operations are required to hold a certificate of competence (COC) relevant to the task that they perform.

While management of animal welfare is now a legal imperative it is also a subject that is a fundamental requirement of integrated food assurance programmes. A good example of this can be demonstrated by the introduction of the new Bord Bia Meat Products Quality Assurance Scheme (MPQAS) standard, which was launched in October 2013.

Both regulation 1099/2009 and the MPQAS standard have, as an underlining theme, the basis of what has become commonly termed the 'five freedoms' i.e. freedom from hunger and thirst; freedom from discomfort; freedom from pain, injury or disease; freedom to express normal behaviour; and, freedom from fear and distress. In later years, a possible sixth freedom crept into this concept and that is the freedom to be free. This is of particular interest in the Irish context where animals, particularly sheep and cattle, spend much of their lifespan roaming around green lush pastures. Of particular relevance in this area is the direct impact of animal welfare on meat safety and quality issues as outlined below.

Animal welfare and the MPQAS standard

Many definitions of animal welfare exist in the literature but, in summary, food assurance standards such as the MPQAS place heavy emphasis on welfare as a system that manages and ensures animal health and husbandry while providing, as far as is practical, a system that promotes normal animal behaviour. Specifically, the MPQAS at abattoir level

focuses on managing animal welfare at all key stages in the process flow chain. This includes steps such as animal transport; animal intake into lairage; lairage management; movement of animals to stunning area; handling of animals in the stun box, stunning, shackling, bleeding; and, ultimately, death. Digging down into this in further detail, abattoirs have to maintain a list of approved animal hauliers, who themselves have to abide by designated codes of practice, for example, the farm animal advisory council guidelines (FAWAC). Animals are checked into lairage on the basis that they are healthy and from approved farms and, should any animals be injured during transit, the abattoir must have a system to deal with these in a humane fashion and under the supervision of the official veterinarian in charge. While in lairage, animals are maintained in their own social groups and in conditions that are managed to ensure adequate freedom to move around with access to fresh water at all times. Prior to slaughter, animals are encouraged to move (poultry are moved in crate modules) to the stunning location under the supervision of trained staff. Specific stunning protocols are then specified for different animal species. Strict protocols must be adhered to for the shackling and bleeding of animals including stun verification and stun-to-stick/initial bleed-time monitoring. As mentioned above, all factory operatives involved in the above steps must now legally hold a COC for the key steps. This COC comprises each individual successfully completing a theoretical examination, which is delivered by an independent training body authorised by the Department of Agriculture, Food and the Marine (DAFM), combined with the successful completion of a supervised practical examination by an authorised veterinary officer. Underpinning the COC, operatives are also requested to attend a DAFM-approved animal welfare training programme.

Role of Teagasc in regulation 1099/2009

Teagasc, Ashtown Food Research Centre (AFRC), Food Industry Development Department has been authorised by DAFM as an official training assessment body for the purpose of the new animal welfare regulations. The animal welfare training programme, which is run in conjunction with the Registered Board of Assessors Ireland, has also been approved by DAFM as a recognised training programme. Regulation 1099/2009 also requires that abattoirs delegate authority and responsibility to an animal welfare officer, who will be in a position to report directly to the business operator. In response to this requirement, Teagasc Food Industry Development Department, in partnership with Registered Board of Assessors Ireland, has also developed a new course for the purpose of training animal welfare officers. To date, approximately 450 meat industry personnel have been trained and undergone COC theory assessments representing in excess of 50 large- and medium-size meat enterprises.

Animal welfare drivers and impact on food quality

Poor welfare practices at producer level and at the key steps from animal transport through into the abattoir can have a serious effect on the final quality of meat. High stress levels resulting from poor welfare management leads to depletion of blood and muscle glycogen levels. This affects final lactic acid levels in the meat post mortem, which influences final optimum pH levels. This can lead to issues such as dark firm dry meat in beef, pale soft exudate in pig meat and likely reduced shelf life in all meat products due to higher pH levels. Other welfare-related quality issues include bruised meat and dirty animals, which require considerable extra resources to rectify and remove. The practice of live clipping of dirty cattle is now largely substituted for online clipping of dead animals. However, dirty animals will still contribute to increased levels of carcass contamination and possible secondary contamination within the abattoir environment due to increased level of aerosols. Overall, these issues of meat quality and safety resulting from poor welfare management and understanding will lead to considerable economic losses for all those concerned in the meat industry.

While this article deals primarily with animal welfare immediately prior to slaughter, there is clearly a legal requirement not to cause any unnecessary pain or distress to any livestock at any stage. Underpinning this are the economic factors as outlined above but other key drivers of welfare are also significant. Major food retailers and food service outlets now require contractual arrangements under which animals must be sourced from assured producers and slaughtered in approved, assurance-recognised abattoirs, for example, using the MPQAS programme. Some major retailers will also verify welfare standards remotely through, for example, using close circuit television monitors positioned at appropriate locations within the abattoir itself. Quality assurance status of fresh meat products is now heavily marketed to consumers at point of sale where recent issues such as the horse meat contamination crisis have further reinforced the requirement for quality, safety and provenance assurance.

Next steps

Assuring the welfare of meat-producing animals is now heavily embedded in legislation and food assurance standards and has a direct impact on the quality and safety of the food we eat. Research into ways of enhancing and improving meat quality and safety post slaughter has been extensively researched and prioritised at Teagasc AFRC over many years, further emphasising the importance of this topic.

Animal welfare management is now a prerequisite for all stakeholders in the meat industry. It involves ensuring that the five animal freedoms are met and, where possible, the sixth animal freedom is addressed and communicated to key stakeholders. Death of animals for meat production is a given; however, the focus has to be on ensuring that the suffering of animal is minimised to the best of our skills and technical ability.

Further research is required in this area, particularly in evaluating and minimising the stress factors that contribute to the quality and safety of the final product. This research needs to be species specific as welfare requirements will vary with species type, breed, sex and weight of animal. Further work is also required in the development of guides to best practice for all key stages involved in the process chain prior to slaughter.

Acknowledgements

This project is funded primarily through industry subscriptions and Teagasc core funding.

Teagasc Animal Ethics Committee

The importance of ethics in animal research and the role of the Teagasc Animal Ethics Committee are outlined by its secretary Dr Laura Boyle.

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There is no legal requirement for ethical approval of research involving animals. However, there are several important drivers of the need for an ethics committee in organisations such as Teagasc where research involving animals is performed. The first is that a growing number of scientific journals have policies on the ethical treatment of animals in research and will only publish papers that adhere to specific ethical guidelines. The second is that external funding is increasingly subject to ethical approval. In response to these drivers, the Director of Research at Teagasc, Dr Frank O'Mara, appointed 11 members to the Teagasc Animal Ethics Committee (TAEC) in July 2012 with the remit to perform ethical evaluations of all experiments involving animals that are conducted by Teagasc staff or on Teagasc sites (see panel). The TAEC had its inaugural meeting in September 2012 and currently convenes four to five times per year reviewing approximately 10 applications at each meeting. To date, over 80 ethical approvals have been issued.

Dr Laura Boyle is TAEC Secretary, Chair of the Moorepark Animal Welfare Body and Animal Ethics Officer with the FP7 ECO FCE project. The TAEC includes Paddy Browne (Chairperson), Laura Boyle (Secretary), Jim Grant (Statistician), John Mee, Stephen Butler, Padraig French, Edward O'Riordan, Padraig O'Kiely, Michael Diskin and Tom Beresford, with administrative support from Majella Kelly (all Teagasc staff), and an external expert from UCD, Dr Nola Leonard.

What is an ethics approval?

An ethics approval from the TAEC guarantees that experiments involving animals adhere to a specific set of moral principles governing the use of animals in research. These moral principles include a responsibility to protect and promote the welfare of the animals used. They are largely based around Russell and Burch's 'Principles of Humane Experimental Techniques' better known as the three R's:

- Reduction – methods that minimise the number of animals used, or maximise the information

gained from a given number of animals.
- Refinement – improvements to husbandry and procedures that minimise actual or potential pain, suffering, distress or lasting harm and/or improve animal welfare.
- Replacement – substitution of conscious living animals with insentient material (invertebrates, computer models, in vitro techniques, etc.).

Polls show that the public expects that where animals are used for research that animal suffering is minimised, alternatives are fully considered, animal suffering has been weighed against potential benefits and that there is supervision to ensure high standards of welfare. Hence the TAEC oversees the use of animals used in Teagasc research by following a set of ethical guidelines centred around a utilitarian approach. A cost-benefit analysis is central to the utilitarian approach whereby the harms to the animals are weighed against the benefits to society. Consideration is given to the following:

- Can it be argued in a credible way that the research in question is important?
- Has the research been conducted before?
- Is the experimental design likely to achieve the objectives of the research?
- Is there no other way of achieving the results?
- Has the experiment been designed to minimise pain, suffering and distress to the animals?
- Will the animals be cared for and housed appropriately?
- Do the researchers and other personnel involved have appropriate training and competency to conduct the research?

By following these ethical guidelines the TAEC lessens the risk that 'costs' are incurred to animals. Such 'costs' could include:

- the wasteful use of animals, such as in cases where experiments are poorly designed and therefore fail to yield useful results;
- the behavioural and physical needs of the animal are not met by the housing or handling facilities;
- unnecessary pain, suffering, distress or lasting harm is caused to animals by the experimental treatments or procedures; and,
- animals die or need to be euthanised

This, in turn, minimises the risk of research that could be potentially damaging to Teagasc's reputation. This is especially important given the increasing visibility of our research programme to the public via its website, open access research journals and social media, etc.

Ethical approval versus experimental licencing

Under the TAEC terms of reference, all research involving animals to be conducted on Teagasc premises or by Teagasc staff or postgraduate students must be submitted to the TAEC for ethical approval. The only exception to this is where the proposed work has already received ethical approval from an ethics committee, which is recognised by the TAEC (e.g., the UCD Animal Research Ethics Committee). However, certain research involving animals also requires an experimental licence under EU legislation (EU Directive 2010/63/EU on the protection of animals for scientific purposes,) which came into force on January 1, 2013. This is a separate legal requirement.

On January 1, 2013, the Health Products Regulatory Authority (HPRA, formerly the Irish Medicines Board) became the competent authority responsible for the implementation of EU Directive 2010/63/EU transposed into Irish law under Statutory Instrument 543 of 2012. The HPRA is responsible for the evaluation and authorisation of projects involving the use of animals in procedures for a fee. Under this legislation a 'procedure' means: "any use, invasive or non-invasive, of an animal for experimental or other scientific purposes, with known or unknown outcome, or educational purposes, which may cause the animal a level of pain, suffering, distress or lasting harm equivalent to, or higher than, that caused by the introduction of a needle in accordance with good veterinary practice."

Based on the definition of procedures described above, experiments involving dietary restrictions, biopsies, blood sampling, painful procedures (e.g., tail docking), anaesthesia, etc., require licensing. Similarly, experiments involving social stress caused by repeated re-mixing, over stocking or social isolation must be licensed. However, experiments that involve measurements such as milk sampling, body condition scoring or weighing, do not require licensing. The requirement for licensing is less clear cut for a myriad of other procedures and the TAEC recommends that, if in doubt, researchers should contact HPRA for advice well in advance of the experiment start date.

At the time of its inception, the relevance of the TAEC to the requirements of the EU legislation was underappreciated. However, it transpired that an ethical review of projects requiring licenses is required. HPRA recognises the workings of the TAEC such that ethical approval from the TAEC obviates the need for HPRA to perform an ethical review. This significantly reduces the cost to Teagasc of experimental licences.

Animal Welfare Bodies

Animal Welfare Bodies (AWB) are an additional requirement of EU Directive 2010/63/EU. Teagasc has three AWBs (based at Moorepark, Grange and Athenry) composed of the farm manager(s) (or 'Animal Care and Welfare Officers' under the Directive), the Compliance Officer (i.e., the person responsible for compliance with the Directive at each site) and at least one other scientific member. Additionally, each AWB has significant input from the designated veterinarian at each site. The primary task of the AWB is focused on giving advice on animal-welfare issues to personnel involved in research with animals and to follow the development and outcome of projects.

There is considerable cross-talk between the TAEC and the three AWBs whereby several members of the TAEC are also AWB members at their respective sites and can, therefore, act as links between the two committees. As previously described, all experiments involving animals proposed at Teagasc sites are reviewed by the TAEC, so procedures involved, start dates, personnel, etc., are known in advance of work commencing. This means that the TAEC can inform the relevant AWB of when particular work is commencing or when procedures requiring closer monitoring are being conducted, for example if they are new to the research team. In turn AWB members can feedback practical information from 'the field' to the TAEC. For example, where the animal care and welfare officers (i.e., farm managers) report an adverse effect associated with a particular procedure to the AWB this is reported back to the TAEC and can inform the TAEC when making decisions regarding severity banding of the same procedure in the future.

Hence, the TAEC plays an important role in Teagasc's continuing implementation and compliance with EU Directive 2010/63/EU. However, the work of the TAEC is vitally important in its own right as it safeguards the moral principles governing research with animals, which enhances Teagasc's reputation as a research performing organisation.

Breeding improved varieties of white clover

White clover evaluation and selection under sheep grazing at Oak Park, Carlow.

Once a forgotten species, the importance of white clover (*Trifolium repens*) to Irish agriculture is well established today.

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White clover is one of the most nutritious species available in grassland production systems. In association with grass, white clover increases the protein, mineral, intake and nutritive value of the total forage. Because of its nitrogen-fixing capacity, white clover has the potential to reduce or, in the case of organic systems, eliminate the need for inorganic nitrogen (N) fertilizer on grazed grassland. Grass/clover swards can produce about 80% of the milk output of grass swards receiving N fertilizer of over 350kg N/ha per year. Grassland-based animal production is a major part of the Irish agricultural economy. Consequently, any improvement in this legume has large potential benefit to this sector.

Teagasc has been breeding white clover for over 50 years at Oak Park, Carlow. Chieftain, Avoca, Susi, Aran and Tara are some of the successful and well-known Teagasc-bred varieties. Changing climate, pests, diseases and farming practices (as dictated by economic and national policy shifts, and new knowledge) mean new varieties are continually required in order to optimise the performance of our grassland. Breeding new varieties offers a low-cost means of improving the profitability of animal production from grassland. There is usually little difference in the price of seed of new and older varieties. Sowing a new, improved variety offers a permanent increase in performance over the lifetime of the variety. In contrast, a management scheme designed to improve crop performance must be continually re-applied each year, at a recurring cost.

Breeding goals

Our goal is to increase the profitability and sustainability of animal production from grassland in Ireland by breeding improved varieties of white clover for Irish farm systems. Teagasc varieties are bred and tested in Ireland under real-world conditions using a combination of cutting and animal grazing over multiple years and locations. The main traits for

genetic improvement are: (i) total and seasonal yield of white clover; (ii) combined yield of clover and companion grass; (iii) persistency; (iv) stolon density; and (v) disease resistance. The programme breeds small, medium and large leaf size varieties.

Variety improvement

The release of a new white clover variety is the culmination of a 15- to 20-year process consisting of three main stages: (i) forage breeding (product development); (ii) independent variety evaluation (product testing); and (iii) commercial seed production (product release).

The breeding process consists of a multistep and cyclic process where the best genotypes (plants) are evaluated, selected and intercrossed to produce a new variety. The process is known as recurrent selection. The generalised method consists of three parts: (i) development of a source population from which to begin selection; (ii) evaluation of individual plants from the source population; and (iii) selection and intercrossing of superior plants to form a new population. Most important forage traits are quantitative and controlled by the joint action of many genes. Recurrent selection increases the frequency of favourable alleles and superior genotypes in the population by repeated cycles of selection and can achieve, in successive cycles of selection, what would almost certainly never be achieved by non-recurrent selection.

The source population from which to begin selection consists of varieties, elite families and introductions from gene banks. Selection is based on phenotypic and genotypic recurrent selection. Phenotypic recurrent selection is selection based on visual observation or physical measurement of the trait and is most useful for traits with high heritability. Genotypic recurrent selection is selection based on progeny performance. In our white clover breeding programme, we mainly use full-sib progeny test selection.

The superior genotypes identified through one cycle of recurrent selection may become the starting point for the next cycle of recurrent selection or may be used to construct new synthetic varieties. A synthetic variety is defined as a population produced by hybridising, in all possible combinations, a number of selected genotypes and which is thereafter maintained by random mating in isolation. The new variety is submitted to the Department of Agriculture, Food and the Marine for independent testing under cutting and grazing. The variety is added to the Ireland Recommended List if it is found to offer improved agronomic performance and its botanical characteristics are distinct from other varieties, uniform and stable (DUS). Commercial seed of Teagasc-bred varieties are produced and sold under license by Goldcrop Ltd. or DLF-Trifolium.

Selection for increased persistency in white clover.

Varieties

Chieftain and Avoca, both bred by Teagasc, are currently the best yielding medium-leaf size white clover varieties on the Ireland Recommended List. In 2014, Iona, a medium-leaf size variety offering outstanding early season growth, was added to the Recommended List. Buddy will be released in 2015. Although a medium-leaf size variety, Buddy offers exceptional persistency and ground cover under tight grazing comparable to a small-leaf size variety. Coolfin is scheduled for release in 2017. Coolfin, a small-leaf size variety, is the highest yielding white clover variety in the Department of Agriculture, Food and the Marine's Recommended List trials. In 2018, Dublin will be released. Dublin is a large-leaf variety offering further improvements in yield and persistency, and greater choice for farmers looking for a variety suitable for grazing and cutting.

White clover has been subjected to very little formal breeding. Genetic variation within and among populations is still extremely high, showing no signs of decreasing. There is no sign that the breeding progress achieved during the past 50 years of forage breeding will not continue for at least the next 50 years.

Acknowledgement

The Teagasc grass and clover breeding programme is funded by Goldcrop Ltd., Carrigtwohill, Co Cork.

Crossing white clover in an insect-proof polytunnel using bumble bees from a commercial hive.

Phosphorus management for profitable and environmentally sustainable farming

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Results of the Teagasc Agricultural Catchments Programme indicate that climate and soil properties have a greater control on phosphorus losses from agricultural catchments than the level of soil fertility and P use on catchment farms.

Enrichment of water-bodies with nitrogen (N) and phosphorus (P), termed eutrophication, can cause rapid vegetation growth, resulting in declines in ecological, recreational and drinking water quality. The EU Nitrates Directive contains a series of measures designed to protect European water resources from nutrient enrichment by reducing nutrient transfers from agricultural land. While many EU countries only implement measures for reducing nitrate losses to water, Ireland's freshwaters are particularly sensitive to P enrichment; therefore, ratification of the Nitrates Directive National Action Programme (NAP) in Ireland also includes limits on the magnitude of P application rates based on the P status of soils. These limits are designed to avoid excessive soil P status (i.e., above the agronomic optimum level – Index 3) and so support the agronomic needs of soils while offering a degree of protection to water resources. Such double-dividends are critical to successfully achieving the food production targets set out in Food Harvest 2020 without compromising water-quality objectives.

Declining soil P

A review of soil samples analysed through Teagasc indicate a declining trend in soil P levels on farms since the introduction of the NAP measures in 2006. This decline may be partly attributed to the NAP limits on P applications and, from an agronomic perspective, there is concern that it might be negatively affecting soil fertility levels. This concern is heightened by the growing recognition that Irish soils have a high capacity to retain P against root extraction, making it unavailable to plants, particularly in heavy clay-rich soils. In order to address this concern, there needs to be better targeting of the replaced P and better use of the soil-P store which is unavailable to plants. This will require a combination of sustained nutrient management (achieved, for example, by soil testing) and biotechnological developments to enable plants roots to extract soil-P more effectively. The effects of soil properties on their P fertility levels are being studied by the Teagasc Agricultural Catchments Programme (ACP) using P trials across a range of soil types and production intensities. These trials will be used to demonstrate optimum nutrient management with a view to informing agronomic policy and NAP reviews.

The 'lag effect'

These declines in soil P levels bode well from a water-quality perspective; however, high resolution monitoring at catchment scales by the ACP reveal why subsequent decreases in river P levels may be slow to emerge – termed the 'lag effect'. Firstly, ACP data show that soil drainage properties can have greater controls on P levels leaving catchment streams than the level of P application on farms and plant-available soil P levels – for example, some of the catchments with moderate to high soil-P levels are showing low P exports in rivers (e.g., the arable catchment in Figures 1 and 2). This is due to the freely-drained nature of their soils, which facilitates vertical movement of water and associated P down through the soil profile and fixation of P to soil particles along the way. On the contrary, some of the catchments with low plant-available soil-P levels are showing higher P exports in rivers (e.g., the grassland catchment in Figure 1 and 2) due to the heavy clay-rich nature of their soils,

which (a) facilitates rapid water flow and P transfer over the soil surface, with limited opportunities for fixation to soil particles before delivery to the river system and (b) enhances the accumulation of P in a form that is not immediately available for plant uptake but is available for mobilisation in runoff. This non-labile P can act as a continuous source for downstream water-bodies for years or decades and, thus, is widely recognised as 'legacy-P'. Secondly, ACP data show that climate, rainfall magnitude in particular, can overwhelm spatial variations in soil properties and plant-available soil-P levels, and has a stronger influence on P levels leaving catchments in stream flow.

Figure 1. Two contrasting ACP catchments: top, an arable catchment with moderate P status well-drained soils and, bottom, a grassland catchment with low P-status poorly-drained clay-rich soils.

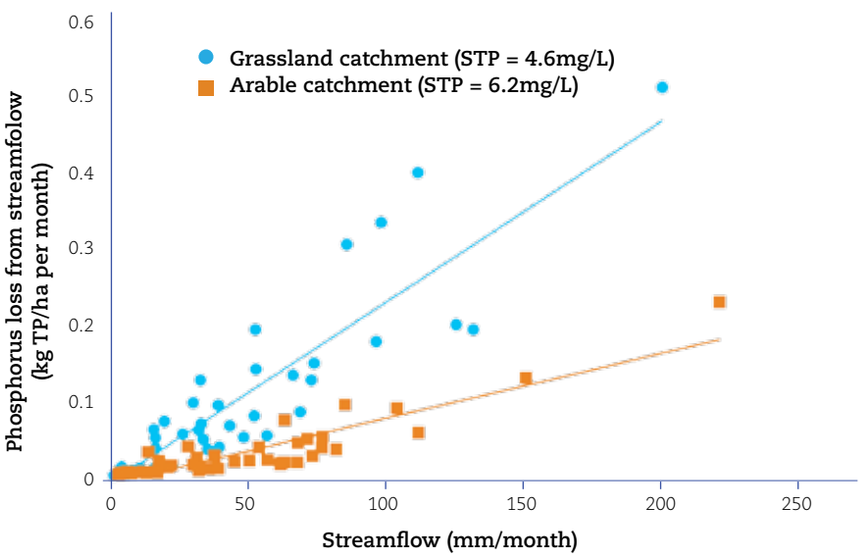

Figure 2. Phosphorus losses in stream flow from two contrasting ACP catchments (see Figure 1). STP represents the mean Soil Test P (i.e., plant-available P) levels in each catchment. TP represents total phosphorus.

Implications for management

These findings have implications for management; in terms of climate controls on P losses, knowledge of rainfall patterns over annual time scales and tools for identifying major rainfall events would help to highlight times when farmers should exercise care with P applications and work is ongoing by the ACP in this area. In terms of the controls of soil drainage properties on P losses, the ACP is using soil drainage information, together with high resolution maps of topography and soil-P levels, to identify 'risky' areas for P loss, here termed critical source areas (CSAs) in five agricultural catchments. Traditionally, CSAs were identified as areas with a high potential for surface runoff and high soil-P levels; however, ACP data has shown that surface runoff from all agricultural soils, rather than high-P soils only, determined P losses between hydrologically contrasting catchments (Figures 1 and 2). This finding challenges the use of the traditional approach to CSA identification in certain catchments and highlights the importance of the mobilisation and pathway elements of the P transfer continuum: source-mobilisation-pathway-delivery-impact. The ACP is currently defining CSAs at the sub-field scale as this is where management needs to be focused.

After identifying CSAs for P loss, the ideal next step would involve putting in place management measures downstream of these areas and ACP research has shown, for example, that mobilised P could be effectively trapped in drainage ditch networks that either already exist or can be slightly modified to ideal dimensions or conditions. There is a growing body of work from other countries with similar P-loss issues where mitigation options specific to their landscape types are being explored and which, with adjustment, could be transferrable to Ireland.

In terms of emerging policy needs, based on the expectation that agriculture must be economically and environmentally sustainable, ACP research is indicating that managing the risk of P loss from CSAs is not likely to be a blanket policy but focused on very small parts of farms in very small areas of larger landscapes. Utilising CAP support mechanisms for agri-environmental measures downstream of these risky areas has great potential to facilitate the need for environmentally sustainable soil fertility in such areas while minimising P losses.

Acknowledgements

This project was conducted within the Agricultural Catchments Programme and was funded by the Department of Agriculture, Food and the Marine. We acknowledge the catchment farmers for their cooperation and access to their land, the ACP team, the Teagasc Walsh fellowship Programme and staff at the Soil, Environment and Land-Use Department, Teagasc, Johnstown Castle.

Detailed references for papers used in the preparation of this article can be found at www.teagasc.ie/agcatchments/publications/








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PhytoFor – protecting Irish forests from disease

Researchers at Teagasc, in conjunction with several other institutions, are gaining a clearer understanding of the biology and life cycle of the pathogen *Phytophthora ramorum* and how it infects Irish forests. The pathogen has devastated several larch plantations since 2010, so much so that larch planting is no longer being supported in Ireland now due to the disease risk.

The genus *Phytophthora* (Greek word meaning "Plant Destroyer") contains many important plant pathogens, including the causal agent of late potato blight, *Phytophthora infestans* and the sudden oak death pathogen, *Phytophthora ramorum*.

P. ramorum is an exotic pathogen of woody plants and trees in Europe and North America with a host range of more than 200 plant species. It was first found causing the rapid death of live oak (*Quercus agrifolia*) and tanoak (*Lithocarpus densiflorus*) trees in California in the late 1990s, giving the disease the common name 'sudden oak death'. In 2000, *P. ramorum* was recorded as causing foliar and stem lesions on ornamental rhododendron in European nurseries (Figure 1), and was officially described as a new species in 2001 by German and Dutch scientists. Between 2000 and 2009 the disease was mostly a threat to the horticulture industry, causing significant yearly losses to woody shrubs like rhododendron, *Viburnum* and *Camellia*. In 2009, severe outbreaks of

Figure 1 *Phytophthora ramorum* infection causing leaf necrosis in rhododendron

the disease were identified in Japanese larch (*Larix kaempferi*) forests in Britain, causing crown dieback (Figure 2) and stem lesions, not only on larch but on several other nearby tree species, including beech (*Fagus sylvatica*), Spanish chestnut (*Castanea sativa*) and noble fir (*Abies procera*). The disease was identified on larch in Ireland in 2010 following surveys by the Forest Service. The epidemic on larch has highlighted the devastating effect that *P. ramorum* can have on trees other than oak, where it was first identified in American forests. *P. ramorum* sporulates heavily on

Figure 2 *P. ramorum* dieback on Japanese larch

Japanese larch, thus driving its spread to nearby trees. The pathogen is currently regulated in Europe and North America so that trees found to be infected must be removed along with all susceptible hosts within a certain radius of the site of infection. Obviously, this has serious economic implications for commercial forestry plantations.

PhytoFor project

The Department of Agriculture, Food and the Marine has funded the PhytoFor project, which seeks to provide information on several important aspects of the biology and epidemiology of the pathogen. The project takes an all-island approach to disease control and involves collaboration between Teagasc, the Agri-Food and Biosciences Institute, Belfast (AFBI), University College Dublin, University of Limerick, Coillte, the Forest Service, and the Plant Health Laboratory of the Department of Agriculture, Food and the Marine. Running from 2012 to 2015, the research utilises more than 300 isolates of *P. ramorum* built up through routine testing of samples between 2004 and 2012 from the North and South of Ireland and also from other countries. The project partners are investigating several aspects of *P. ramorum* biology/epidemiology, including:

- Characterising the Irish population of *P. ramorum* based on both its phenotypic (e.g. growth rate, pathogenicity) and genotypic (phylogenetic) characteristics.
- Describing the host (larch) and pathogen (*P. ramorum*) responses on a molecular level during a successful pathogen-host infection using RNA sequencing.
- Providing optimised methodologies for the sampling, isolation and molecular confirmation of the disease in infected larch plant material.
- Using field sites to characterise the spread and survival patterns of *P. ramorum* in infected larch forests.

Characteristics of the Irish *P. ramorum* population

Four distinct types or 'lineages' of *P. ramorum* are known, two from North America (NA1 and NA2) and two from Europe (EU1 and the recently identified EU2). Previous studies have found that isolates of the NA1 lineage are generally less aggressive than isolates of either the EU1 or NA2 lineages. The PhytoFor project has identified that *P. ramorum* isolates in the Republic of Ireland are all EU1 type; while in Northern Ireland they are predominantly the recently identified EU2 type.

Phytophthora species are largely asexually reproducing organisms (clonal), and genetic analysis of *P. ramorum* populations have found no evidence of successful mating under natural conditions. Laboratory trials have confirmed that *P. ramorum* is heterothallic (two different mating types: A1 and A2); however, mating success is very low even under ideal conditions in laboratory trials. The prospect of successful mating between two individuals of *P. ramorum* is worrying because sexual reproduction has the potential to produce off-spring with very unpredictable characteristics, including increased host range or virulence.

In order to assess whether or not *P. ramorum* isolates in Ireland are capable of cross-breeding to produce new off-spring by sexual reproduction, we conducted *in vitro* mating assays to identify the mating characteristics of Irish *P. ramorum* isolates. Previous studies have found that the EU1 population was almost exclusively A1 mating type, and the EU2 lineage was entirely A1 mating type. Both North American lineages (NA1 and NA2) are exclusively A2 mating type. Up to now, the mating type of only six Irish isolates of *P. ramorum* had been confirmed. We paired mycelial fragments of isolates of unknown mating types of *P. ramorum* from Ireland with that of known mating type tester isolates of *P. ramorum*. The pairings were incubated in the dark at 20°C and checked weekly for the formation of gametangia, which is an indication of a successful A1 x A2 pairing.

In total, we have identified the mating types of 35 isolates, 29 of which are from Ireland (Table 1). The production of gametangia was very rare, and often several replicates of each unknown-known pairing were established before gametangia were noted. Our results indicate that only the A1 mating type is currently present in Ireland. Furthermore, we found that even in ideal conditions, successful mating of *P. ramorum* x *P. ramorum* is very rare. Taken together, these results suggest that there is a very low threat of novel phenotypes/genotypes of *P. ramorum* being generated via sexual reproduction between two *P. ramorum* parent strains in the wild in Ireland. This is good news for Irish forestry but we must be vigilant and alert to the possibility that new and aggressive plant pathogens may emerge at any time to threaten commercial forestry. Results from other research tasks will be reported at a later date.

Table 1. Mating types of *P. ramorum* isolates

Source of *P. ramorum* isolates tested	Mating Type A1	Mating Type A2
Republic of Ireland: 15 EU1 isolates	15	
Northern Ireland: 14 EU2 isolates	14	
England and Scotland:1 EU1 and 2 EU2 isolates	3	
US: 2 NA1 and 1 NA2 isolates		3

Acknowledgements

The PhytoFor project is funded by the Department of Agriculture, Food and the Marine.

Pesticide regulations and cereal disease

The loss of the azole fungicides will threaten our ability to control both septoria tritici blotch of wheat (left) and Rhynchosporium scald of barley (right).

Implications of increased pesticide regulations on cereal disease control in Ireland are discussed by researchers in Teagasc's cereal disease control programme.

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Irish wheat and barley crops consistently produce some of the highest yields globally. The combination of an abundant supply of water, minor fluctuations in temperature and long summer day lengths provide the ideal conditions for Irish cereal crops to convert sunlight into carbohydrates throughout June and July. Unfortunately, it is these same environmental conditions that allow wet weather diseases to thrive, with diseases such as septoria tritici blotch of wheat and Rhynchosporium of barley particularly damaging. By either reducing the capacity of the crop to capture sunlight or by directly infecting the developing grain, cereal diseases have the potential to reduce yields by upwards of 50%. To counteract this, growers utilise all available means of control including: varietal resistance, crop rotation and agronomic practices, such as sowing date and fungicide application. While ideally, each of these practices should contribute to control in practice, they are limited either by commercial restraints associated with resistant varieties (e.g., poor yields) or lack of viable rotational crops, as well as the ability of fungal pathogens to produce wind-dispersed spores, coupled, of course, with unfavourable climatic conditions. This has resulted in increased reliance being placed upon cereal disease control through the application of fungicides.

EC strategy on sustainable use of pesticides

In 2006, the European Commission adopted the Thematic Strategy on the sustainable usage of pesticides. Within this strategy, changes to how pesticides are registered among the Member States were established under the Regulation 1107/2009 concerning the placing of plant protection products on the market in each State. This regulation superseded the previous directive 91/414/EEC under which judgments were based on whether a pesticide posed a 'risk' to human or environmental wellbeing. Under the new regulation these judgments are to be made based on the potential 'hazard' of the pesticide. A risk-based approach included consideration of where and how the product would be used but the hazard approach will be based only on the intrinsic properties of the pesticide itself. While the exclusion of pesticides that are intrinsically toxic, such as mutagenic pesticides, or those that are extremely persistent in the environment is unlikely to affect the availability of currently relied upon pesticides, the potential removal from the market of pesticides, which may be defined as endocrine disruptors, will have major implications for cereal production in Ireland.

Possible banned pesticides

The definition of an endocrine disruptor has yet to be decided; however, it is possible that some of the most active azole fungicides (along with a number of other active ingredients) will be banned. These include epoxiconazole and tebuconazole (and potentially prothioconazole), which are widely applied to Irish wheat, barley and oat crops to control a wide variety of fungal diseases (see Tables 1 and 2, adapted from

Table 1. Activity of fungicide groups registered for use on winter wheat.

Fungicide group	No. of fungicides registered[a]	Septoria tritici blotch	Eyespot	Rusts	Mildew	*Fusarium* spp.
Triazoles	8	Good (mixed formulation)[b] Poor-moderate (solo)[b]	Good[c]	Excellent	Limited	Good[c]
Imidazole	1	Moderate	Good	Moderate	Poor	Moderate
SDHIs (succinate dehydrogenase inhibitors)	5	Excellent	Good[c]	Good	Moderate	Poor
QoIs (Quinone outside inhibitor)	5	Poor	Poor	Good	Poor	Poor
Morpholines	2	Poor	Moderate	Moderate	Excellent	Limited
AP-fungicides (Anilino-pyrimidenes)	1	Poor	Good	Poor	Poor	Poor
Mildewicides	3	Poor	Poor	Poor	Excellent	Poor
Multi-site - Chlorothalonil	1	Good (protection only)	Poor	Poor	Poor	Poor
Multi-site - Folpet	1	Good (protection only)	Poor	Poor	Poor	Poor
Multi-site - Mancozeb	1	Moderate	Poor	Poor	Poor	Poor

[a]Number of different active ingredients registered in 2014.
[b]Strains of *Zymoseptoria tritici* with reduced sensitivity to the most active triazole fungicides are now present in Northern-European populations and have impacted upon field efficacy of solo products. Mixtures of the most active triazoles still provide excellent field efficacy when applied at the recommended rates.
[c]Fungicide dependent.

Table 2. Activity of fungicide groups registered for use on winter barley in the Republic of Ireland and Northern Ireland.

Fungicide group	No. of fungicides[a]	Rhynchosporium	Net blotch	Ramularia	Eyespot	Rust	Mildew	*Fusarium* spp.
Triazoles	7	Excellent[b,c]	Poor-Good[b]	Poor-Good[b]	Good[b]	Excellent	Limited	Good[c]
Imidazole	1	Moderate	Poor	Poor	Good	Moderate	Poor	Moderate
SDHIs (succinate dehydrogenase inhibitors)	5	Excellent	Excellent	Excellent	Good	Good	Moderate	Poor
QoIs (Quinone outside inhibitor)	6	Good	Good	Poor	Poor	Good	Poor	Poor
Morpholines	2	Moderate	Moderate	Poor	Moderate	Moderate	Excellent	Limited
AP-fungicides (Anilino-pyrimidenes)	1	Moderate	Moderate	Poor	Good	Poor	Poor	Poor
Mildewicides	3	Poor	Poor	Poor	Poor	Poor	Excellent	Poor
Multi-site - Chlorothalonil	1	Moderate	Moderate	Good	Poor	Poor	Poor	Poor
Multi-site - Folpet	1	Moderate	Moderate	Moderate	Poor	Poor	Poor	Poor

[a]Number of different active ingredients registered in 2014.
[b]Fungicide dependent.
[c]Strains with reduced sensitivity to particular triazoles have been detected in European populations.

Jess *et al.* 2014). In their absence, and with no new fungicide groups expected for a number of years, increased emphasis will be placed immediately on the remaining groups of fungicides.

Septoria tritici

Control of septoria tritici blotch in wheat will be almost exclusively reliant on the SDHIs and the multi-site chlorothalonil. As a solely protectant fungicide, chlorothalonil must be present on the leaf prior to the pathogen arriving. Under Irish climatic conditions, this can be tricky and it is for this reason that fungicides such as the azoles and SDHIs with the ability to provide curative activity are essential. As single site active ingredients, the SDHIs are at a medium to high risk of resistance development and, with septoria isolates with reduced sensitivity already detected in Europe, their continued efficacy over the coming years, were they to be relied heavily upon, must be questionable.

While alternatives are available for diseases such as septoria on wheat, prothioconazole is currently the most active fungicide for the control of Fusarium Head Blight on both wheat and barley and its application in wet seasons, such as 2012, can make the difference between a profit and loss. Prothioconazole is also the most relied upon fungicide for the control of almost all the major barley pathogens (*Rhynchosporium commune, Pyrenophora teres* and *Ramularia collo-cygni*). Although the range of fungicides with activity against these is greater than those available to control septoria, the same issues arise, principally the development of resistance. Key to delaying resistance emergence and subsequent spread is the mixing of active fungicides with different modes of action. If the decision is taken to ban azoles, then the production of certain crop species such as wheat may become uneconomic in Ireland. However, irrespective of what decision is taken on whether fungicides such as the azoles are to be banned within Europe, increased emphasis must be placed upon the integration of all control measures available for disease control that reduce the reliance on chemical control such as the cultivation of resistant varieties.

Acknowledgements

Teagasc's cereal disease programme is funded by the Teagasc core fund and by the Department of Agriculture, Food and the Marine's Research Stimulus fund.

Reference

Jess, S., Kildea, S., Moody, A., Rennick, G., Murchie, A. K. and Cooke, L. R. (2014) 'European Union policy on pesticides: implications for agriculture in Ireland'. *Pest Management Science*, 70: 1646–1654. doi: 10.1002/ps.3801.

Advances in fruit and vegetable production

Irish Tomato Crop displaying its 30th and 31st fruit trusses. Each plant is approximately 30 metres long and the crop will produce 450-500 tonnes of fruit/ha per year. With increased carbon dioxide supplementation yield should increase 10-15%. Only biopesticides, predators and parasitoids have been applied to this crop, old leaves are purposely left on the ground in piles as they act as refuges for beneficial insects.

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Over 140 people, including growers, researchers, knowledge-transfer experts and students, attended the second National Protected Crops Conference at Teagasc Ashtown in October. Presentations on the day covered the important areas of water quality, consumer perception, technological advancements, energy and integrated pest management.

The benefit of light

The development of LED technology has the potential to significantly increase yields and improve crop quality. However, the capital cost of full overhead and inter crop lighting is significant, currently reported to be approximately €1.5 million per hectare (ha) of 'high-wire' crops (tomatoes, peppers, cucumbers). However, it is necessary to establish what exactly the expected crop yield increase will be in order to allow growers to estimate the commercial potential of such a system. Tim Haworth of CambridgeHOK presented an update of the first year's commercial experiments using LED on tomato crops in the UK. The experiment on a cherry tomato variety, Sweet Rosso, indicated a 4-4.5kg/m^2 increase in yield in tomatoes in the 10-week period between weeks eight and 18. Plant growth was also significantly advanced, with the LED-treated plants one truss ahead of the control after three weeks and

two trusses ahead after eight weeks' production. As tomato crops move into August, it is normal to remove some plants, to reduce the overall plant density. While control crops were reduced to three plants per m^2, due to the increased availability of light, LED treated crops were only reduced to 3.6 plants per m^2 , which increases the overall potential yield of the crop. Weekly production with LED from week 19 to 41, on average, increased production by 21% with only 16% more plant density compared to the control. Results up to week 41 showed LED-treated crops yielded 29kg/m^2 versus 22.3kg/m^2 in the control, with a projected yield to the end of the season of 33kg/m^2 in LED-treated crop versus 26.6 kg/m^2 in the commercial control (an extra 64 tonnes of tomatoes per Ha per season). This represents a very significant yield increase over a growing season and will help growers to assess any potential investment in LEDs.

The importance of carbon dioxide

However, in order to run LED lights, a grower will obviously face higher electricity costs. Combined heat and power (CHP) engines have been used extensively in Holland and elsewhere, to heat glasshouses but also to generate electricity to power supplementary lighting. CHP plants convert fossil fuels into heat, power and carbon dioxide. Carbon dioxide is critical to sustaining good growth in glasshouses with an actively growing tomato crop requiring 200-250kg CO_2/ha/hr for optimal growth. Given that this scenario is likely to occur when the sun is naturally warming the glasshouse the requirement for heat is not as critical as the requirement for CO_2, therefore the ability to generate CO_2 with less heat might be preferable. A conventional boiler will convert 100kW of fuel into 95 kWt of heat and 1.8kg CO_2/mn^3 NG, whereas a CHP will convert 100kW of fuel into 50kWt of heat, 41kWe of electricity and 1.8kg CO_2/mn^3 NG. This means less heat needs to be stored in buffer tanks and the grower also has the benefit of generating electricity, either to power supplementary lighting or exporting it to the national grid. Such an investment is very significant and the completion of such a large project is very challenging. This was the focus of a presentation from Matt Foley, a tomato grower from North Dublin, who gave details of the recent installation and commissioning of a CHP engine at his tomato nursery, which was the culmination of a three-year project. While only running for part of this growing season, he reported that the increased availability of CO_2 was having a beneficial effect on crop yield and crop quality. He stressed the significant challenge in successfully implementing the project, which involved extensive planning and feasibility studies. For growers who may not be willing to tackle such a challenging project, Ross Hibbs of CambridgeHOK, explained the recent development of two CHP projects in the UK where private power generation companies fund and manage the installation of CHP plants. The grower is required to provide the land for the installation of the engine and will enter into an agreement to take waste heat from the engine to heat their glasshouse. This can result in fixed and predictable energy costs for growers for up to 20 years.

Integrated pest management

Crop protection, and integrated pest management (IPM) in particular, was the focus of a number of presentations. While IPM and the use of beneficial predators and parasitoids in protected crops is now established practice, Dr Gerben Messelink of Wageningen University and Research Centre, highlighted instances where current biological controls are not effective enough and need

A parasitized mummy of a Potato Peach Aphid (top) and surviving Potato Peach Aphid (*Myzus persicae*).

to be improved. Some pest species, such as potato peach aphid (*Myzus persicae*) are not easily controlled, either by parasitic wasps or predatory mites, whereas in the control of red spider mites, there is a suggestion that different species of predatory mites added to crops are impacting on each other's efficacy. Caterpillar control has been an ongoing issue in glasshouses, Trichogramma wasps are not sufficiently effective, Macrolophus predatory bugs, will consume caterpillar eggs and while *Bacillus thuringiensis* (Bt) sprays are effective against small caterpillars, control against larger caterpillars is still limited to synthetic pesticides. It was also announced at the conference that a Bt spray will be registered for use in Ireland in 2015, which is a welcome development. Different strategies such as the use of banker plants were discussed. Banker plants have traditionally been cereal crops, infested with *Sitobion avenae* (Grain Aphid), which support parasitoid reproduction, namely the wasps *Aphelinus abdominalis* or *Aphidius ervi* in the absence of an aphid outbreak on the commercial crop. The concept is that you will have a developed parasitoid population present in the glasshouse when the pest species appears. This system has had its challenges, as the effect of hyperparasitoids (parasitoids that parasitise the primary parasitoids of aphid species) such as *Dendrocerus aphidum* is causing significant late summer decrease in aphid parasitoids numbers, leading to increasing aphid populations. Further research is needed to improve this approach. This concept of 'Banker plants' is now being applied to other beneficial insects, such as hoverflies, by interplanting commercial crops with buckwheat, Fagopyrum and *Crambe hispanica* to act as nectar source to encourage hoverfly development. Biological crop protection is a dynamic process that requires constant re-evaluation. Many growers are now reporting that, by using good hygiene controls, biopesticides and biological controls, they do not regularly need to use pesticides. Given the increasing legislative and public pressure on the use of pesticides, the advances in 'biological' pest control in protected crops show what might be possible in the future for other crops, but achieving this at economically affordable levels will be a significant challenge for researchers, knowledge-transfer personnel and growers over the coming decades.

A full list of the presentations from the day are available on the Teagasc website.

Empowering rural communities

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The main findings of the report of the Commission for the Economic Development of Rural Areas (CEDRA) are summarised below.

Earlier this year, Taoiseach Enda Kenny launched the report of the Commission for the Economic Development of Rural Areas (CEDRA). CEDRA was established by Government in recognition that rural areas have been hit harder by the downturn with unemployment increasing at nearly double the rate of urban areas.

Despite an excellent 1999 White Paper, construction effectively became the rural development strategy during the latter Celtic Tiger Years. However, this strategy proved to be unsustainable, particularly for rural areas that were more heavily reliant on this sector.

CEDRA comprised a voluntary Commission with experts in economic development, chaired by Pat Spillane, supported by a secretariat of Teagasc, the Department of the Environment, Communities and Local Government and the Western Development Commission. In preparing the report, an extensive consultation was undertaken with over 100 meetings, as well as a detailed research exercise.

Thirty-eight recommendations were made by CEDRA, comprising both structural and sectoral recommendations. These recommendations were backed up by evidence provided in a research report prepared by the secretariat on the basis of a research programme undertaken by Teagasc, the Western Development Commission published in a book, *Rural Economic Development in Ireland*, published at the Teagasc National Rural Development Conference in September.

Empowering rural communities

While the agri-food sector is growing rapidly, there are lots of opportunities for our food SMEs to grow. However, given their scale, they find it difficult to export. More targeted support of State agencies such as the Food Works programme could increase their export share.

Similarly, despite national tourism growth, there remain many underexploited tourism opportunities

in rural areas. There are many examples of potential local tourism destinations requiring a dedicated national rural tourism strategy and improved tourist products.

A key recommendation to support the local economy, particularly among rural towns, was a targeted rural-towns stimulus package aimed at revitalising those towns that had been most affected by the downturn. This work built upon a study undertaken by Teagasc that received very large media coverage in the spring, in relation to the Rural Towns Index.

The exporting sector has been doing very well; however, increasing employment by rural workers will require them to have the right skills and for National Skills Strategies to recognise different needs across the country.

Attracting FDI and the role of local authorities

Also, emphasis was placed on making rural areas more attractive for Foreign Direct Investment through improved infrastructure and through a higher focus placed on rural niche investment by State agencies. Broadband was raised as an issue in all public meetings. The existence of broadband is not sufficient; the quality, however, is important for businesses to be able to explore online opportunities.

The Commission welcomed the increased role of local authorities in supporting economic development. However, it emphasised the need for it to be community-led and to build upon existing strengths, partnering with local development companies. CEDRA also highlighted that economic development requires a different skillset than regulation or service provision, particularly in terms of greater risk-taking.

EU and Government support

The Commission emphasised the need for the Government to take the necessary steps now to ensure that the CEDRA report is given strong recognition in the Government's Partnership Agreement with the European Union, which will govern the next phase of EU structural fund support for Ireland over the next seven years.

Rural economic development is cross-cutting in nature, requiring the input of many departments and agencies. Complex problems such as this pose coordination challenges for existing national governance structures. This is particularly the case in an era of very tight public finances where agencies focus on maximising their impact on core rather than cross-cutting issues.

Until the publication of the report, there existed no structure within Government to coordinate rural economic development. As a result it has been low priority for over a decade. The National Spatial Strategy focused mainly on urban growth and had relatively little to say about rural areas and was almost non-existent for rural towns.

Appointment of Government Minister

The highest priority recommendation, therefore, of the Commission was that the appropriate governmental coordination structures be put in place and in particular that a specific Senior Government Minister has responsibility for the coordination of rural economic development.

A new department, however, was not considered a priority. While there has been a Department for Rural Affairs, its focus was on operational measures rather than the strategic coordination of mainstream economic development and infrastructure provision, which will have more impact than specific schemes.

At the launch, the Taoiseach, to his credit, has given his personal commitment to coordinating the implementation of the report via his Cabinet Sub-Committees, while Minister Hogan announced the establishment of a cross-cutting implementation committee to support this.

Unlocking potential

The previous White Paper led to the establishment of a Cabinet Committee on social inclusion, drugs and rural development. It was the fervent view of the Commission however, that rural development was not a social problem, rather the report focused on unlocking economic potential that exists in rural areas to enable rural areas to make a full contribution to the national economic recovery.

In the Government reshuffle during the summer, Ann Phelan, TD for Carlow-Kilkenny was appointed Minister of State for Rural Affairs with particular responsibility for implementing the CEDRA report, which is a very high-profile response to the findings of the Commission and the supporting research programme, led by Teagasc and the Western Development Commission. Minister Phelan is very familiar with Teagasc, as both the Oak Park campus and Kildalton College are within her constituency, and she recognises the capacity of Teagasc in supporting Government objectives in the area of Rural Economic Development.

On her appointment, Minister Phelan established an Interdepartmental Working Group, comprising officials from all Government Departments with a role in implementing the strategy. Teagasc is represented on this group and is advising on research to support decision-making by Government. She will report to Government with a more refined operational action plan for Rural Economic Development at the turn of the year.

CEDRA reports are available online: http://ruralireland.ie/index.php/cedra-reports

The publication 'Rural Economic Development in Ireland' is available at: http://www.teagasc.ie/publications/view_publication.aspx?PublicationID=3297

Carbon sequestration by hedgerows in Ireland

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Dr Kevin Black, FERS Ltd, Dublin,
Garret Mullooley (not pictured) and **Alejandro Poveda (not pictured)**, Treemetrics Ltd., Cork
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A preliminary study on the hedgerow stocks of Ireland has been carried out in order to estimate their potential in carbon sequestration.

Hedgerows are understood to be an important part of the Irish agricultural landscape. They play significant roles as reservoirs of biodiversity, landscape features, water buffers and their primary functions in stock control. These multiple roles have been recognised in agricultural policy, from REPS (Rural Environment Protection Scheme) through to GLAS (Green Low-Carbon Agri-Environment Scheme), with millions of euro spent on improving and expanding the national hedgerow stock; their recent designation as landscape features makes this value explicit. So it's perhaps surprising that our understanding of the distribution and quality of the national hedgerow stock is only partial. Some County Councils have carried out hedgerow surveys in order to characterise the hedgerow population in the county. These surveys contain lots of information but only estimates of hedgerow cover in those counties.

Teagasc created the first draft map of hedgerow and scrub cover (THM05) for Ireland using automatic image interpretation of aerial photography. This map database shows that a large area of the country is covered by hedgerow and scrub. In fact, 6% of the country is covered in hedgerow and scrub; equivalent in size to Co Tipperary (compare with forestry which covered 10% of the country in the same period).

One reason why Teagasc mapped hedgerows was to assess their contribution to national carbon budgets in the context of greenhouse gas (GHG) emissions. Under article 3.4 of the Kyoto agreement land use management can be included in accounting of national carbon budgets. This element of accounting is voluntary and so far Ireland has chosen not to include it in its national accounts. Research has indicated that grassland and cropland management, including hedgerow management, is likely to be a net sink (absorbs more than emits) for carbon.

Contribution of hedgerows to carbon budget

To calculate the contribution of hedgerows to the national carbon budget we need the total area covered and an estimate of the amount of biomass (living growing vegetation) above ground in a hedge. Biomass is a measure of the carbon locked into the hedgerow. How much per year it absorbs and adds to this "locked in" amount is the sequestration.

In traditional forestry environments biomass is estimated through the measurement of simple characteristics such as species type and height for a sample of trees in the stand. These figures can then be converted to biomass (very similar to measuring the volume of timber in a stand) using standard conversion factors. This sort of approach is much more difficult in hedgerows;

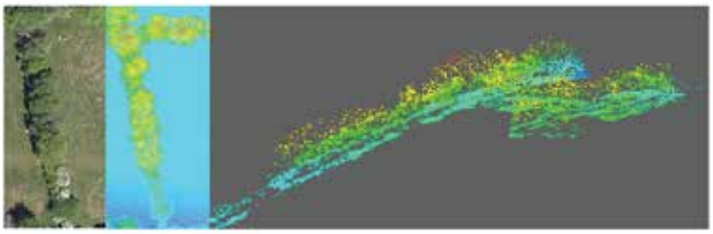

Figure 1. A typical hedgerow, as seen from above in aerial photography (left) and from above and in profile from the Lidar scan.

they are much more varied in composition than forest stands and the parameters needed to convert sample measurements to biomass do not exist, including calculating the below ground biomass (in the roots) that goes along with the above ground biomass.

It is unlikely that a ground-based survey of all hedgerows and non-forest woodland patches ("scrub") would be carried out due to the costs involved. Remote Sensing (RS) techniques (the technology of measuring from a distance), like satellite imaging or Google Earth, can capture all the data needed quickly and cheaply. This project was carried out to test the effectiveness of these RS techniques, specifically Lidar, to measure the 3D structure of hedgerows, eliminating the need for field work. These RS derived properties were then used to estimate above ground biomass and carbon sequestration. We then designed a survey that would provide a national estimate of above-ground biomass in hedgerows, providing a cost-benefit analysis of doing so.

3D Lidar

Lidar stands for 'light detection and ranging', and is analogous to radar (radio detection and ranging). The system comprises very accurate Global Positioning System (GPS) and orientation sensors (allowing us to locate the Lidar sensor within a few cm in three dimensions) combined with a laser scanning system. In this project we used both airborne and terrestrial scanners: one is mounted on aircraft and flown above the hedgerows; the other on a tripod and scans the hedgerows from the side but the principal of operation is the same. The laser emits high frequency pulses of light. These pulses shine down on the target and some are reflected back to the sensor. The on board computer records when the pulses were sent and how long it took for them to arrive back at the sensor. A simple calculation then allows for the distance from the sensor to the target to be calculated. As the sensor knows exactly where it is, it can very precisely calculate the location of whatever the laser pulse bounced off. This process is carried out thousands of times a second as the laser sweeps across a target and the aircraft carries it along and creates very detailed 3D models of the target. We flew an exceptionally detailed scan (in Frenchpark, Co Roscommon) with more than 10 pulses recorded per square metre. This means that our scan reflected off individual leaves, penetrated deep into the hedgerow to reflect off twigs and stems and down to the ground area, revealing, walls, ditches and banks on which the hedgerows grew.

By manipulating the characteristics of the returned pulses (and other ancillary information) we can automatically detect hedgerows in the landscape and can characterise the hedgerow into a number of types. We can also calculate height, width, volume and density and it is these calculations that are used to estimate the aboveground biomass of the hedgerow.

Mini-forest models

Using software specially developed for forestry applications (CARBWARE) the hedgerows were modelled as mini-forest stands. We can convert these physical characteristics of hedgerows, scaled up to nationally, into estimates of total sequestration potential and using estimates of hedgerow stock change from the National Forest Inventory, annual net-net sequestration (the current mechanism for claiming emission reductions due to land use change). See Table 1.

Table 1: Results of preliminary analysis

	Estimate	Lower/upper limit to estimate
Above-ground hedgerow sequestration potential (tCO_2/ha per year)	1.6	0.5-2.7
Total hedgerow sequestration potential (tCO_2/ha per year)	1.9	0.6-3.2
Above ground scrub sequestration potential (tCO_2/ha per year)	2.6	2.2-2.8
Total scrub sequestration potential (tCO_2/ha per year)	3.1	2.7-3.4
National hedge and scrub annual sequestration (tCO_2/ha per year)	0.7 million	0.3-1.1
Annual net-net removal (tCO_2)	9,200	3,000-17,000

Incorporating hedgerows into national land use change reporting has the potential to increase the carbon sink in the sector by between 8% and 28%. The current price per tonne of carbon in the ETS is too low to justify a full Lidar inventory on the value of net-net carbon credits. However, the net-net change is likely underreported as there is no research on the sequestration potential of managed hedgerows compared to unmanaged. Irrespective of this, measuring sequestration of hedgerows will be important for fully accounting the sequestration potential of permanent grassland systems in any future net-GHG reduction commitments for agriculture from Europe.

Next steps in understanding potential of hedgerows

The work here represents an important step in better understanding the composition of the national hedgerow stock and its role in carbon sequestration but the figures quoted are estimates based on pared down forest models applied to a small sample of hedgerow scans. For a more complete understanding we need:

- hedgerow specific biomass/carbon models (this means scanning and destructively testing a hedgerow for its carbon content),
- figures on the relationship between above and below ground biomass in hedgerows, and importantly,
- field experiments over a number of seasons to quantify the effect of management on the sequestration potential of hedgerows.

This project was funded under the Environmental Protection Agency Climate Change Research Programme 2007-2013.
The final report can be accessed at: port: http://www.epa.ie/pubs/reports/research/climate/ccrp-32-for-webFINAL.pdf

Review and outlook for farm income 2015

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Teagasc economists reflect on the highs and lows of 2014 for Ireland's agri sector and look forward to 2015.

At the end of each year, Teagasc economists estimate the economic outturn for each of the principal sectors of Irish agriculture in order to arrive at an overall estimate of agricultural income analogous to the income measure calculated in the Teagasc National Farm Survey (NFS). At the same time, they assess likely developments in each sector over the short term, to arrive at a forecast average income level for the year ahead (Teagasc, 2014).

Invariably there will be some unanticipated shocks to the system, which mean that the forecast is imperfect, but in general these forecasts are a valuable planning tool for farmers, the food industry, policymakers and the banking sector.

Review of 2014

In terms of weather conditions, 2014 was one of the best years for grass-growing conditions in Ireland in living memory and marked a contrast to the difficult operating environment of 2012 and 2013. Lower grassland input expenditure was driven by lower levels of feed and fertilizer usage and lower prices.

Market conditions for milk producers and beef finishers took a downturn in 2014 and the decrease in prices eroded the benefit of lower feed, fertilizer and fuel bills. At 12 cent per litre, the average dairy net margin in 2014 was unchanged on the previous year, as milk prices and production costs are estimated to both have fallen by 2 cent per litre. Beef finishers also experienced lower production costs, but the impact of lower costs did not fully offset the impact of lower finished cattle prices and beef finisher gross margins declined by 9% in 2014.

While suckler farmers saw their average output prices fall, the estimated decrease in input

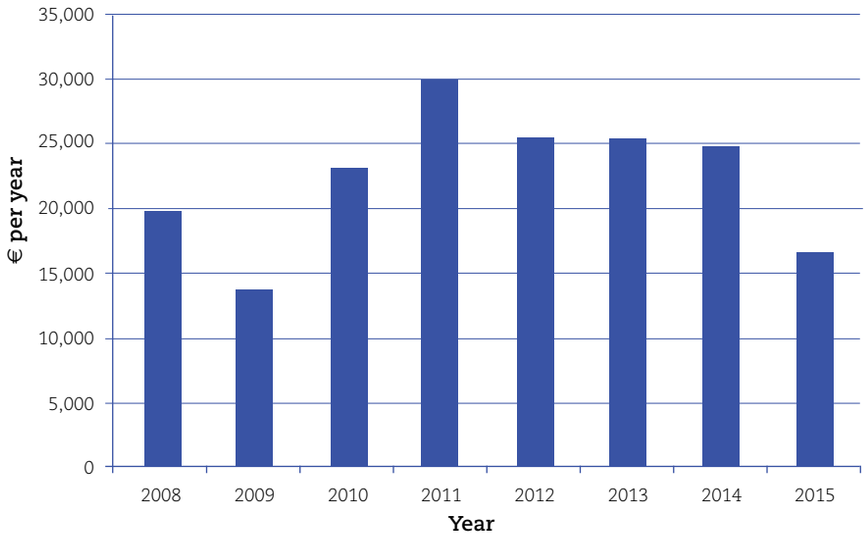

Figure 1: Teagasc NFS average farm income, with estimate for 2014 and forecast for 2015.
Source: Teagasc NFS and authors' estimates and forecasts.

expenditure meant that 2014 margins improved on levels earned in 2013.

Sheep farmers saw their margins improve in 2014, as their production costs decreased, while lamb prices on average were higher than in 2013.

Cereal yields for major crops were above normal in 2014, but a large global harvest triggered a steep drop in cereal prices. While cereal direct costs were down slightly, this was insufficient to negate the drop in output value. Consequently, cereal margins were down for nearly all crops in 2014.

Pig producers experienced a decrease in pig prices in 2014, which was mainly due to the Russian embargo, but benefitted from declining feed prices through most of the year. Overall, their margins increased in 2014.

Overall, these changes in margin at the sector level are indicative of a 3% drop in farm income in 2014, relative to 2013.

Outlook for 2015

In 2014, we saw a demand shock with the imposition of the Russian embargo and a supply shock due to a surge in global milk output, neither of which were anticipated in advance. Uncertainties of this kind may again emerge in 2015, making it challenging to forecast income in the year ahead.

Weather conditions can play a significant role in determining grassland and tillage sector incomes, given the impact it can have on yields and production costs. Since it is not possible to forecast weather for the year ahead, we must assume that weather conditions reflect a long-term average.

On this basis, feed usage levels in 2015 should be similar to those of 2014. Feed prices are likely to be lower in the first half of 2015 and higher in the second half, but, on average, feed bills for grassland systems are forecast to be little changed on the 2014 level. Pig producers may experience a slight increase in their feed prices. The euro is expected to be weaker against the US dollar in 2015 than it was in 2014. Allied with concern regarding the security of international fertilizer supplies, this means that fertilizer prices are forecast to be higher in 2015. With no anticipated change in fertilizer use, fertilizer expenditure is forecast to rise.

If the sudden and dramatic drop in oil prices in the latter stages of 2014 persists there will be considerable savings in fuel bills in 2015. Electricity prices reflect a mix of energy prices (coal, gas, oil and renewables) and significant capital costs, so the fall in oil prices may have little impact.

A substantial fall in farm-gate milk prices is forecast for 2015. Global milk production growth in 2014 has outpaced the growth in demand for dairy products and a surplus has emerged, which will depress prices for much of 2015. In Ireland, the forecast reduction in milk prices is 28% . This would take the annual average milk price down to 27 cent per litre, a 10 cent per litre drop on the estimated average figure for 2014.

Irish beef prices should improve in 2015 and with costs of production relatively unchanged, margins should be up for all beef systems. Sheep prices are expected to remain stable in 2015. A change to the Sheep Grassland Scheme payment will impact on margins, but will not affect incomes.

Stock levels on international grain markets remain at relatively low levels, in spite of the large global harvest in 2014. Cereal prices in 2015 will, therefore, be highly dependent on growing conditions globally. For harvest 2015, Irish cereal prices are forecast to rise by 10%. If Irish yields revert to normal levels from the high of 2014, then cereal margins in 2015 will be only very slightly improved on 2014 levels.

Pigmeat prices are set to fall slightly in 2015 due to increased EU supplies, and marginally higher feed prices will also negatively impact on pig margins in 2015.

The interannual variation in Irish agricultural income is heavily associated with changes in dairy margins from year to year. Much of the rest of Irish farm income is derived from the subsidy system and hence remains relatively stable, on a year-to-year basis. For the Irish dairy sector, 2015 is shaping up to be very much like 2009, with dairy incomes set to be more than halved. This will have a strong negative impact on income for the agriculture sector as a whole. Averaging across all of Irish agriculture, a decline in income of 25% is forecast in 2015. Using the narrower Teagasc NFS farm income definition, which excludes some enterprises and smaller farms, the forecast decrease is steeper, with an average decline of 30% in prospect.

References

Teagasc. 2014. 'Annual Review and Outlook 2015'. Rural Economy Development Programme, Teagasc. Available online: http://www.teagasc.ie/publications/2014/3414/Outlook_2015.pdf

Events

JANUARY

6-9 January — *RDS, Dublin*

BT Young Scientists exhibition

Visit Teagasc at BT Young Scientists exhibition.
Contact: Lance.Obrien@teagasc.ie

28-29 January — *Alexander Hotel, Dublin*

Joint Agricultural GHG Research Initiative-Ireland/UK greenhouse gas (GHG) Platform Meeting (by invite only)

The meeting will jointly exhibit research finding of the UK GHG Platform and the Irish Agricultural GHG Initiative. Topics will include emissions inventory refinement, mitigation of methane and nitrous oxide and carbon sequestration across various land uses.
Contact: Gary.Lanigan@teagasc.ie

29 January — *Lyrath Estate Hotel, Kilkenny*

National Tillage conference

The national tillage conference will provide the most up-to-date information on recent changes to the CAP affecting tillage farmers. It will also provide the latest technical information on a range of topical subjects including: disease control for the coming season, break crop agronomy from the Teagasc/IFA grain levy programme and spring barley agronomy.
Contact: Eleanor.Butler@teagasc.ie

MARCH

9-10 March — *Tullamore Court Hotel, Tullamore, Co Offaly*

Agricultural Research Forum

The objective of the meeting is to provide an opportunity for the presentation and publication of new scientific information relating to the sciences of agriculture (including animal and crop science, molecular biology and biotechnology), environment, soil, food, agri-economics and forestry. The conference places emphasis on novel, high-quality research and on the professional presentation of results. The forum will provide an opportunity for scientists, specialists, advisors and others working in the above areas to interact and exchange views. Participation by industry personnel is particularly welcome. Contact: mark.mcgee@teagasc.ie

23 March

Teagasc Lectures Series Inaugural Lecture – Darwinian Agriculture

Guest speaker Professor R. Ford Denison, Adjunct Professor in Ecology & Evolution, University of Minnesota, Professor Emeritus, UC Davis will present on 'Darwinian Agriculture: How Understanding Evolution Can Improve Agriculture'. As human populations grow and resources are depleted, agriculture will need to use land, water, and other resources more efficiently and without sacrificing long-term sustainability, Darwinian Agriculture presents an entirely new approach to these challenges, one that draws on the principles of evolution and natural selection.
Contact: Lance.OBrien@Teagasc.ie

JUNE

20 June — *Teagasc, Mellows Campus, Athenry, Co Galway*

Sheep2015

This is the major sheep industry event for 2015. There will be a very strong emphasis on technology transfer with 10 villages covering: breeding, grassland, hill sheep, nutrition, flock health, environment, education, wool, marketing and the Teagasc Research Programme. Visits to the Teagasc Sheep Demonstration farm will also feature. A series of workshop will run throughout the day covering practical aspects of sheep husbandry from: dosing, selecting lambs for slaughter, dealing with lameness, selecting ewes and rams for breeding etc. It is expected that the Sheep Breed Societies will have a significant exhibits of their sheep with some also having their National Championships at the event. It is expected that there will be in excess of 100 trade stands. A significant meat industry display and cooking demonstration will also feature. The organising Committee consists of representatives from: Teagasc, UCD, Sheep Ireland, Bord Bia, the Department of Agriculture, Food and the Marine and the *Irish Farmers Journal*.
Contact: norina.coppinger@teagasc.ie

OCTOBER

13 October — *Kilbrin, Co. Cork*

Research on 1st & 2nd Thinning of Conifers

Teagasc, as part of its forestry research programme has established a new thinning trial in Kilbrin, Co. Cork. The research is aimed at providing growers information about the effect of thinning on the growth and development of the forest crop and the optimum treatment to produce a commercial crop. It is possible that rotation ages could be significantly lowered on highly productive sites. Financial analysis indicates that a robust first thinning close to marginal thinning intensity yields the best return on investment, and if thinning is to be considered stands should be thinned early to offset the risks of windblow.
Further details to be supplied later in 2015

20 October — *Cavan Crystal Hotel, Cavan*
21 October — *Horse & Jockey Hotel, Thurles*

Teagasc Pig Farmers' Conference 2015

This conference features a number of presentations covering a broad array of topics relating to nutrition, performance and animal health. It also features a research update on current projects and a poster session by students involved in the research programme at Moorepark. This provides attendees with the opportunity to meet with our researchers and students to find out more about the projects on-going in the Pig Development Department.
Contact Ciaran.Carroll@teagasc.ie

For a list of Teagasc's food industry training schedule (food safety, food law, animal welfare, quality assurance, microbiology, cheese making, calculating meat content, laboratory auditing) please see: http://www.teagasc.ie/food/research/training/schedule.asp
For presentations from previous Teagasc events see: http://www.teagasc.ie/publications/