TResearch
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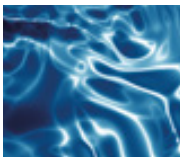

PLASMA
A novel method for cleaning food contact surfaces

APHID GENETICS
Understanding the DNA of the ultimate crop pest

TEAM SPOTLIGHT
A mobile app that brings technology into the field

Picture of health

Researchers are leading work to improve the health and happiness of animals on farms, as public interest in animal welfare increases

Food security: The impact of the Ukraine invasion on Ireland pp.6-7

Teagasc
Agriculture and Food Development Authority

Welcome

Every issue, when reading the articles for *TResearch*, I feel proud and impressed by the ingenuity and innovation evident across Teagasc's food research programme.

For example, in this issue Teagasc's Talita Aline Comunian and André Brodkorb, working with colleagues in Germany and France, are looking at the use of pea protein to encapsulate bioactive compounds with a human health benefit (in this case omega-3 and quercetin). Their work shows that pea protein could be a viable alternative to animal and dairy proteins for delivery of bioactive compounds (p16).

Kieran Kilcawley and Holly Clarke (p34) are using gas-chromatography-olfactometry to investigate how cows' diets affect the aroma of raw milk. The study focuses on volatile organic compounds, as these are responsible for the odour of milk and, therefore, impact sensory perception. It compares raw milk from cows fed outdoors on pasture-based systems (perennial ryegrass) to cows fed indoors on concentrates (total mixed ration) systems.

Bhavya Mysore Lokesh and colleagues tackle the problems of chlorine residues from disinfectants used in the food industry and chlorine-resistant microorganisms (p36). They are looking at plasma (ionised gas) as a sanitiser for cleaning-in-place procedures on spray dryers and hot plate exchangers in the dairy industry.

The efforts of Teagasc experts in collaboration with key partners continue to drive up standards and improve sustainability throughout the industry. I hope you find the articles in this issue of value to your work.

Catriona Boyle
Editor, *TResearch* magazine, Teagasc

I ngach eagrán, agus mé ag léamh na n-alt le haghaidh TResearch, mothaím bródúil agus tógtha leis an intleachtacht agus an nuálaíocht a fheictear ar fud chlár taighde bia Teagasc.

Mar shampla, san eagrán seo, tá Talita Aline Comunian agus André Brodkorb as Teagasc ag obair le comhghleacaithe sa Ghearmáin agus sa Fhrainc, ag féachaint ar úsáid próitéiní piseanna chun comhdhúile bithghníomhacha a bhfuil tairbhe do shláinte an duine ag baint leo a chuimsiú (óimige 3 agus quercetin sa chás seo). Léirítear ina gcuid oibre go bhféadfadh próitéin piseanna a bheith ina rogha eile inmharthana ar phróitéiní ainmhíocha agus déiríochta chun comhdhúile bithghníomhacha a sheachadadh (lch 16).

Tá úsáid á baint ag Kieran Kilcawley agus Holly Clarke (lch 34) as gás-crómatagrafaíocht-boltanaimhéadrachta chun iniúchadh a dhéanamh ar an tionchar a bhíonn ag aistí bia bó ar bholadh bainne amh. Dírítear sa staidéar ar chomhdhúile orgánacha so-ghalaithe, toisc go bhfuil siad sin freagrach as boladh bainne agus, dá bhrí sin, as aireachtáil chéadfach tionchair. Déantar comparáid ann idir bainne amh ó bha a bheathaítear faoin aer ar chórais bunaithe ar fhéarach (seagalach ilbhliantúil) agus ba a bheathaítear faoi dhíon ar chórais tiubhaithe (cion iomlán measctha).

Tugann Bhavya Mysore Lokesh agus a chomhghleacaithe aghaidh ar na fadhbanna maidir le hiarmhair chlóirín ó dhífhabhtáin a úsáidtear sa tionscal bia agus miocrorgánaigh atá frithsheasmhach in aghaidh clóirín (lch 36). Tá siad ag féachaint ar phlasma (gás ianaithe) mar dhíghalrán do ghnáthaimh ghlantacháin atá i bhfeidhm ar spraethriomadóirí agus ar mhalartóirí plátaí teo sa tionscal déiríochta.

Leanann iarrachtaí shaineolaithe Teagasc i gcomhar le príomh-chomhpháirtithe le caighdeáin a ardú agus le hinbhuanaitheacht a fheabhsú ar fud an tionscail. Tá súil agam go bhfuil na hailt san eagrán seo luachmhar do do chuid oibre.

Catriona Boyle
Eagarthóir, iris *TResearch*, Teagasc

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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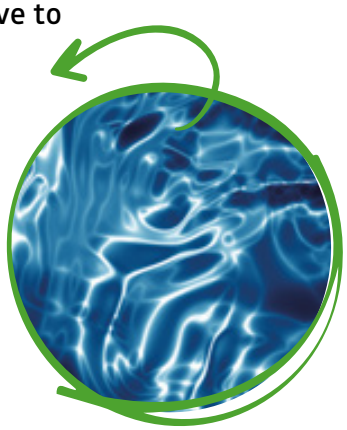


Teagasc hosts conference to tackle pine weevil problem


Adult pine weevil

Teagasc recently held an integrated pest management conference in collaboration with Maynooth University and the Department of Agriculture, Food and the Marine, to find solutions to tackle the prevalent pine weevil pest problem facing reforestation sites.

Hylobius abietis – commonly known as the large pine weevil – is an insect pest that causes substantial plant mortality in reforestation sites. Felling a coniferous crop produces a large increase in breeding material for the pine weevil.

Young trees (both conifer and broadleaf) used for restocking are liable to be heavily attacked by adult pine weevils feeding on the stem from the root collar upwards, and heavy damage can completely girdle stems and cause plant death.

Nuala Ni Fhlatharta, Head of the Teagasc Forestry Development Department, says: "The large pine weevil is the most important reforestation pest in Ireland. They kill about 50% of unprotected seedlings, which increases re-establishment costs such as insecticide application, replacing plants and additional weeding."

John Casey, Teagasc Forestry Advisor, adds: "One third of reforestation costs could be down to pine weevil control. Whilst the cost of controlling these pests is high, the potential cost of failure and replanting is higher."


Representatives from Teagasc, Maynooth University and the Department of Agriculture, Food and the Marine at the integrated pest management conference

Integrated pest management is an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices and the use of resistant varieties.

Louise McNamara, Teagasc Entomology Research Officer, works on pest management options. She says: "The high number of pine weevils in Ireland makes control more challenging. Physical protections are often not enough on high pressure sites, meaning we will still require pesticides in the future."

During the conference, Teagasc and partners evaluated the different integrated pest management options available to tackle the problem at hand.

Addressing anthelmintic resistance

Grazing sheep are continually exposed to stomach worms. Sheep develop immunity to them over time, but they can cause ill-thrift and disease in lambs. Worms are currently controlled by the use of wormer drugs, of which there are five classes: white, yellow, clear, orange and purple (the last two classes are new actives). However, anthelmintic resistance (the ability of worms to survive a wormer dose that should kill them) is increasing, so care should be taken when deciding which wormer to use.

69% White wormers fail on 69% of farms

48% Yellow wormers fail on 48% of farms

38% Clear wormers fail on 38% of farms

Four actions that will slow the further development of wormer resistance on sheep farms in Ireland are:

1. Don't treat adult ewes for stomach worms unless there is a demonstrated need.
2. Use only white wormers to treat Nematodirus disease in lambs.
3. Quarantine and drench bought-in sheep with a new active to prevent bringing in resistant worms.
4. Use faecal egg counts to know when treatment is needed, and to check the treatment has worked.

Find out more here ▶▶ teagasc.ie/media/website/publications/2020/Control-of-Stomach-Worms-Flyer.pdf

Teagasc-hosted researcher wins British Ecological Society journal prize

Teagasc-hosted researcher Dina in 't Zandt has been awarded the British Ecological Society's John L Harper Early Career Researcher Award. The prize is given each year to the best paper written by a researcher at the start of their career in the *Journal of Ecology*.

Dina, who is funded and employed by the Czech Academy of Sciences and is currently hosted at Teagasc's Johnstown Castle Environment Research Centre, won the prize for their research article investigating plant-soil feedback and species abundance fluctuations.

In the study, conducted at Radboud University, Dina and co-authors combined a 31-year plant abundance dataset with a greenhouse experiment, to test whether dominant plant species are prevented from outcompeting less-dominant species because they accumulate negative soil effects.

They found that, on average, the most abundant plant species were also the species that showed the strongest negative own soil effects, and that, over time, significant cyclic relations occurred between species fluctuations in abundance and negative soil effects.

Dina says: "Our findings present a novel balance between a plant species' success and its limitations, which we propose to be driven by soil nutrient availability.

"This paper stands out due to the exceptionally long time period it covers, the cyclicity it uncovered and the presented conceptual framework to reconcile the complexity of the findings."

Dina in 't Zandt is a hosted researcher at Teagasc Johnstown Castle

News in brief

240

Teagasc recently hosted the 7th **International Conference on Food Digestion** in Cork. The conference was a huge success, with **240 delegates** attending from **29 countries**.

(L-R) Teagasc scientists Andre Brodkorb and Linda Giblin with celebrity chef Rachel Allen, Ballymaloe Cookery School, at the conference

Horticulture crop input prices have risen significantly between March 2021 to 2022, more recently due to the invasion of Ukraine. There has been a sharp increase in the cost of energy, labour, packaging materials, fertiliser and a range of other inputs. Teagasc estimates that total input costs have increased by between **13% and 49%**, depending on enterprise type.

26

During 2021, Teagasc's Technology Transfer team worked with researchers to compile **26 invention disclosures** capturing novel intellectual property, alongside filing **six new patents**, supporting and enhancing innovation and entrepreneurship between Teagasc, the business community and other stakeholders.

Teagasc economists claim a **decline in the average family farm income (FFI) in Ireland in 2022 is highly likely**, despite the fact it is estimated to have increased by 20 per cent in 2021. According to Teagasc's recently published **2022 Outlook Report**, this is due to the fact that output price increases will fail to offset the rise in production costs.

Safety net:
food security in Ireland

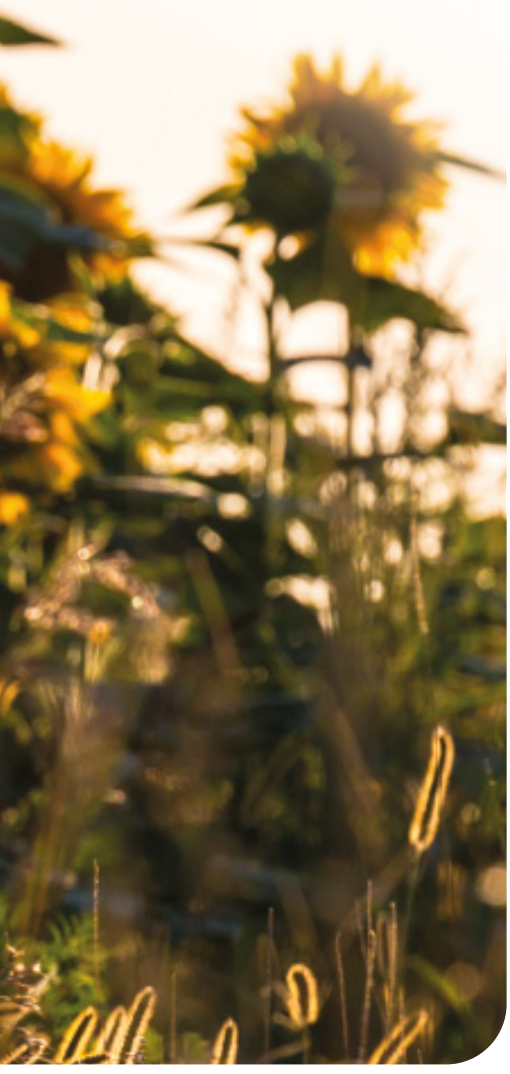
The Russian invasion of Ukraine has led to a global increase in food costs, worsening food security problems in some countries, and introducing it to others. Here, Teagasc's Head of Rural Economy Development Programme Kevin Hanrahan examines food security in Ireland, and the potential implications of rising food prices.

The concept of food security has economic, social and cultural dimensions, but fundamentally, it is about supplies of food being available and people having the economic resources to purchase the available supplies of food that meet their physiological needs and cultural preferences.

Ukraine is an important exporter of agricultural commodities such as wheat, maize and sunflower seeds, and the illegal invasion of Ukraine by Russia has had a dramatic impact on exports of these goods. It has also prevented some Ukrainian farmers from planting their land with crops this spring.

Both of these impacts, together with the impact of sanctions on the Russian Federation, will reduce the supply of grains and oilseeds from the Black Sea region on the world market. With global supply of grain and oilseeds reduced but demand unchanged, grain and oilseed prices have increased dramatically. The prices of other agricultural goods that use grain and oilseeds as inputs have also increased, including meat and dairy production.

Higher agricultural output prices over the coming months will be reflected in increases in food prices for consumers in Ireland and all over the world.



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Supporting low income households

Ireland is, in a global context, a very high-income country, and Irish residents on average have command over sufficient economic resources to ensure that food security is not a concern. However, there are some food consumers and households on low and fixed incomes, for whom the current and likely future increases in food prices will pose food security challenges.

The prospect of very large increases in food prices will reduce the economic access that consumers on low incomes have to food. The appropriate policy response in Ireland to such short-term food insecurity is the provision of targeted income transfers to poor consumers that will provide them economic access to healthy and nutritious food. At a global level, there are countries who are large net importers of food, where a large share of consumers are on very low incomes. For these countries and their generally poor consumers, expenditure on food often accounts for the majority of total income.

The disruption to exports of grains and oilseeds from the Black Sea region and the resulting dramatic increase in food prices poses real societal level food security concerns. The United Nations' World Food Programme will need additional funds to assist such countries to access the dramatically more expensive supplies of grains and oilseeds.

Food availability

The second dimension of food security relates to food availability. Ireland is a very large net exporter of temperate agricultural commodities. This means that, in particular for meat- and dairy-based foods, Ireland produces more than enough to feed itself many times over. By supplying food to consumers in other countries, Ireland plays an important role in ensuring the food security of others.

Whilst being a net exporter of meat and dairy products, Ireland is a net importer of fruits, vegetables, grains and oilseeds. This import dependence might appear to pose a food security vulnerability for Ireland. However, our membership of the EU ensures that this is not a concern.

The vast majority of Irish food imports are from fellow EU member states. As a member of the European Union, Ireland is part of one of the largest and most varied and integrated food markets in the world: the Single Market. Our affluence provides Irish consumers with purchasing power to effectively command access to food, whilst our membership of the EU provides access to more than sufficient and varied food products to ensure food security.

Factfile

According to the United Nations, food security means that all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their food preferences and dietary needs for an active and healthy life.

The role of trade in food security

Free trade between EU member states is guaranteed by the laws of the EU. It ensures that Ireland has access to supplies of food from all over the EU, just as food consumers from all over the EU have unencumbered access to imports of food from Ireland.

Autarky – the idea that being self-sufficient either at an individual, household, community or societal level is preferable to trading with other people, communities, societies or countries – is an ancient but fundamentally inappropriate response to the challenge of food security.

The current crisis is due to the impact of the Russian war in Ukraine on exports of food, combined with low levels of economic development and low incomes in many large net food importers. Freer trade, not autarky, leads to economic development that both raises incomes and provides reliable access to stable supplies of food (and other goods and services) from other places. It is hard to see what role, if any, restricting trade can play in addressing food security.

Allowing individuals and societies to exploit their comparative advantage and specialise in what they are relatively good at is the safest path both to economic development and to medium- to long-term food security.

In the short-term, in the face of high food prices, the appropriate response in Ireland is to provide targeted assistance to those on low incomes. At a global level, the resources provided to the World Food Programme must be increased. T

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Understanding the genetic blueprint of the grain aphid

By unravelling the DNA sequence of the English grain aphid, Teagasc is providing novel insights that support research into insecticide resistance and mechanisms of viral transmission.

Aphids are the ultimate crop pest, thanks to their mode of feeding and their ability to reproduce in vast numbers and adapt to the challenges they face in natural and agricultural settings.

They feed with specialised mouthparts from the phloem of their plant host. The phloem is made of living tissue that transports soluble organic compounds to parts of the plant that need it. Feeding here disrupts this process and damages the plant.

Of the estimated 4,300 aphid species that have been recorded on over 300 plant families, around 100 species are considered economically and agriculturally important pests.

Sitobion avenae – the English grain aphid – is a significant pest of cereals worldwide. It is found on numerous species of grasses, including all the cereals and pasture grasses of temperate regions.

In Ireland, the grain aphid is considered one of the main pests of spring and winter barley, as it is a major vector of barley yellow dwarf virus (BYDV), which infects cereals and can significantly reduce crop yield. The virus itself cannot be treated, so control relies on limiting transmission from aphids, which requires insecticide spray applications (e.g., pyrethroids).

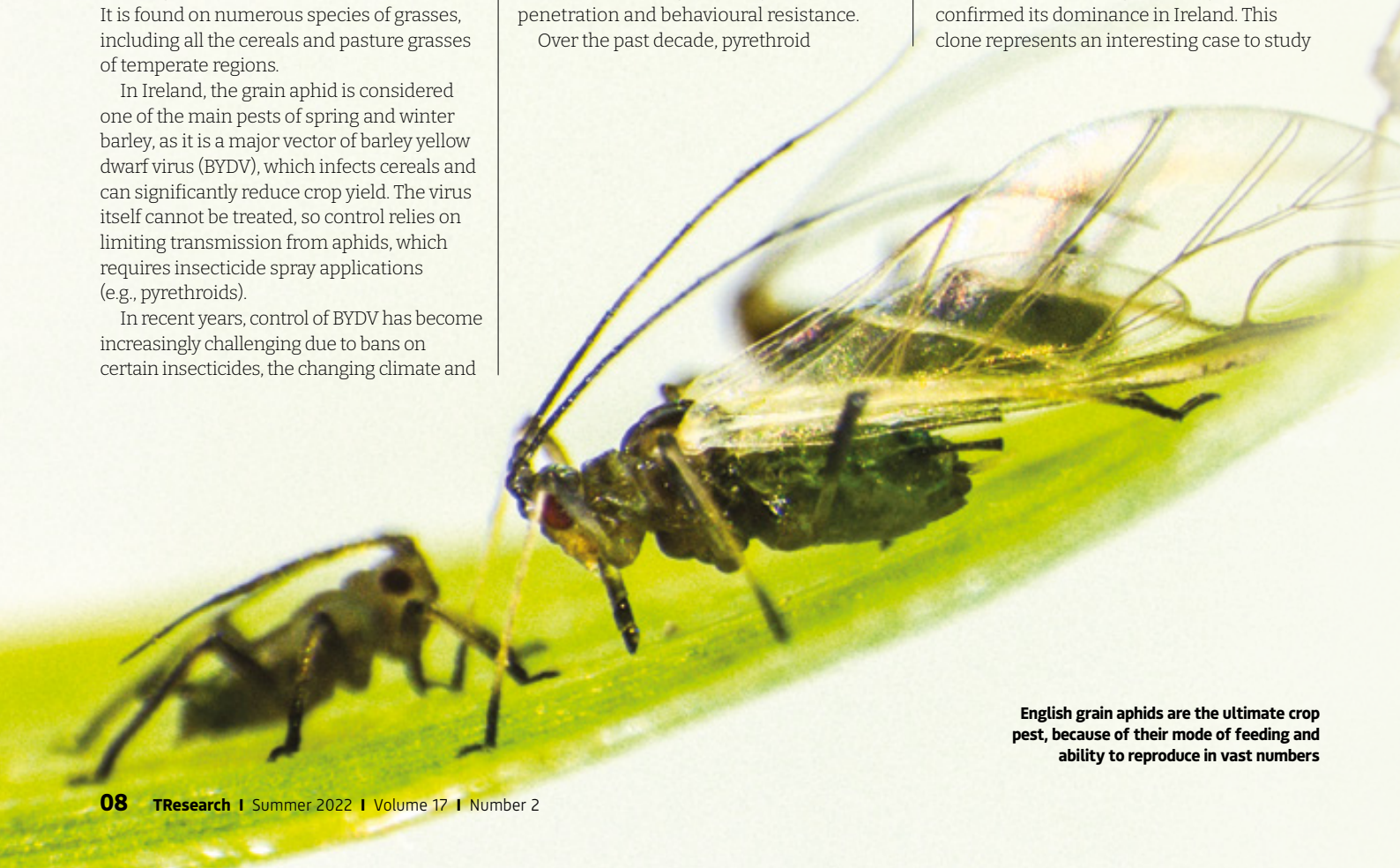
In recent years, control of BYDV has become increasingly challenging due to bans on certain insecticides, the changing climate and the emergence of insecticide resistance. To support research into mechanisms of viral transmission and aphid behaviour, Teagasc has used data to look into the grain aphid's DNA.

Emerging insecticide resistance

Insecticide resistance is an increasing problem for agriculture, forestry and public health. Aphids frequently exhibit insecticide resistance; this can be attributed to several mechanisms, including metabolic (by detoxification), target-site (by mutations), penetration and behavioural resistance.

Over the past decade, pyrethroid resistant clones of the grain aphid have been frequently detected across the UK and Ireland. The most common resistance mechanism is a target-site mutation termed 'knockdown resistance', which reduces sensitivity to pyrethroids, giving aphids a higher probability of survival. Pyrethroids are currently the primary insecticide used to control cereal aphids and BYDV.

Resistant grain aphids were thought to be derived from a single dominant and established clone in England and Scotland named SA3, and a Teagasc survey has confirmed its dominance in Ireland. This clone represents an interesting case to study



English grain aphids are the ultimate crop pest, because of their mode of feeding and ability to reproduce in vast numbers

Field plots with symptoms of barley yellow dwarf virus (BYDV) infection

A fascinating insect

Much of our understanding of aphid biology has arisen from the sequencing and release of genomes for numerous aphid species. Each one provides new insights into this multifaceted insect, such as:

- **Aphids don't require sexual reproduction – each female carries embryos that themselves contain viable embryos**
- **Aphids can send signals to their unborn offspring to develop wings**
- **Aphids can switch sexes so that males are available for sexual reproduction, usually at the onset of winter.**

the mechanisms behind the evolution of insecticide resistance and the impacts of resistance on BYDV transmission. However, despite it being a major agricultural pest of cereals, no reference genome sequence was available for the grain aphid, which has impeded research.

Analysing genetic code

Sequencing the genome of a species involves 'reading' its entire genetic code, which describes how to build and maintain a living organism. Like humans, the grain aphid is diploid, meaning it has two copies of each chromosome.

In their work, the project researchers took advantage of the latest DNA sequencing technology to generate long and highly accurate sequencing reads, and create a diploid assembly of this highly heterozygous (variation in the genetic code between chromosomes) genome. This has resulted in the publication of the first high-quality genome sequence of nearly one billion 'letters' that make up the grain aphid's genetic code.

Located within this genetic code are protein coding genes necessary for the key processes and functions of an organism's cells, and those responsible for the characteristics and features the researchers are interested in understanding.

Analysis of the genome identified 31,007 protein coding genes, several of which belong to gene families that have been linked with metabolic resistance to plant defence compounds and insecticides. In particular, a relatively high number of glutathione-S-transferase (GSTs) was identified in the grain aphid, when compared to other aphid species. This included GSTs that were specific to the grain aphid.

GSTs are of interest because they have been implicated in detoxification of pyrethroids in other insects, and are a target of future research to understand metabolic resistance.

In addition to obtaining the DNA sequence of the aphid, the researchers also sequenced the genome of its obligate bacterial endosymbiont (an organism that forms a symbiotic relationship with another cell or organism) *Buchera aphidicola*. This bacterial endosymbiont is crucial for aphid survival as it provides essential amino acids that are absent from the diet of sap-feeding aphids.

Through this study, the researchers were able to assemble the complete genome of the grain aphid endosymbiont, and identify 572 protein coding genes. A greater understanding of this symbiotic relationship may lead to the future development of control strategies based on endosymbiont disruption.

Supporting future research

The availability of the DNA sequence of the grain aphid genome, in particular the SA3 resistant clone, will now allow researchers to better understand the mechanisms and identify the molecular and genetic adaptations responsible for insecticide resistance.

Understanding aphid resistance is fundamental to planning control schemes that rationalise pesticide use and reduce economic losses. This genome assembly adds to the growing collection of high-quality aphid genome assemblies, and will provide a solid foundation for future studies of grain aphid biology, and for comparative genomic analysis with other aphid species. T

ACKNOWLEDGEMENTS

We would like to give special thanks to the co-authors of the study this article is based on: Michael Gaffney (Teagasc), Peter Thorpe (University of St Andrews), Gaynor Malloch (The James Hutton Institute) and Tom Wilkinson (University College Dublin).

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Comfortable sow, healthier piglets

Bettering the housing conditions of pregnant sows reduces long-term stress and improves mother and offspring welfare.

Long-term (chronic) stress negatively impacts the health and welfare of pregnant sows. This can lead to poor sow performance, such as a reduced number of piglets produced.

Chronic stress during pregnancy can also negatively impact the development of piglets as they grow *in utero*. This can have life-long effects on the piglets, including reduced birth weights, and changes in their behaviour, ability to learn and the way they cope during stressful situations.

It can also impact their ability to fight diseases. Reduced immunity results in poor welfare and performance, especially when the piglets are separated from their mother during weaning – one of the most stressful events in a piglet's life. Weaning stress makes piglets vulnerable to diseases, which require treatment with antibiotics. However, overuse and misuse of antibiotics contribute to the current growing threat of antimicrobial resistance to both humans and animals.

Reducing chronic stress experienced by pregnant mothers could play a crucial role in ensuring good piglet health, resilience and welfare, and could help combat antimicrobial resistance. To date, aspects of sow housing and management that contribute to chronic stress remain under-investigated, so researchers at Teagasc conducted a study to explore this area in more detail.

Experimenting with pen conditions

Two factors in sow housing with the potential to reduce chronic stress are: the improvement of physical comfort whilst lying, and satisfying motivations to explore and forage.

As part of this study, our researchers improved pens for housing pregnant sows on commercial farms by providing rubber lying mats (to improve physical comfort) and straw and natural fibre ropes (to satisfy sows' exploratory needs). They then evaluated the effects these improvements had on chronic stress and the welfare of sows, as well as the health and welfare of their piglets.

Gestation in sows lasts 3.75 months. For the study, one month into this gestation period, 120 sows were assigned to either conventional (control) or improved pens.

All pens had full length feeding stalls and a fully slatted floor. The conventional pens were typical of gestating sow housing in Ireland; they were equipped with two blocks of wood and two chains suspended within the group area as enrichment. The improved pens also had this, as well as rubber mats, a length of manila rope in each feeding stall and straw provided in three racks: one in the middle and one at each end of the pen.

> **Good welfare acts like a preventative medicine for health conditions in both sows and their offspring.**

Mapping stress indicators

Sow locomotory ability (their capability to move independently from place to place) was assessed using a visual analogue scale at different stages of pregnancy: one month into gestation (at the start of the study), around day 57 (the middle of the gestation) and at the end (one week before birth).

The behaviour of the sows was observed at similar times. The first category of behaviour was oral stereotypical behaviours – repetitive, invariant behaviours, indicative of a lack of satiety. Examples include sham chewing, mouth stretching, palate grinding, sucking and tongue flicking. Aggressive behaviours were also recorded.

Right and left eye tear staining – a chronic stress indicator – were scored a week before farrowing (the process of birthing a litter of pigs). The number of piglets born alive, dead and mummified were also counted at farrowing, and throughout lactation the amount of diarrhoea in the farrowing crate was scored approximately every second day, as an indication of piglet health.


Sows in improved pens had better locomotion scores

Effects on sows and their piglets

Sows housed in the improved pens had better locomotion scores in mid- and late pregnancy than sows housed in the conventional pens, reflecting the beneficial effect of the rubber mats on their leg health and reduced lameness. They also had a better right and left eye tear stain score, which indicated they were less stressed.

These findings were supported by the fact that sows in the improved pens performed fewer oral stereotypes in mid- and late pregnancy than those in the conventional pens. In fact, they tended to perform fewer stereotypical behaviours just 72 hours after entry into the improved pens. This confirms previous findings on the beneficial impact of straw on oral stereotypical behaviours in sows.

Levels of aggressive behaviour were lower in improved pens than in conventional ones upon entry to the pen, likely related to the initial novelty of the enrichment, which acted as a distraction and ameliorated aggression. Interestingly, however, levels of aggression in improved pens were higher than conventional pens in late pregnancy. This occurred in the loose area of the pens, indicating it was likely due to competition for access to straw enrichment devices.

High maternal stress levels during early to mid-pregnancy are associated with piglet losses. Any piglet that dies after the formation of its skeleton (anytime between day 38 and 45) is not reabsorbed by the sow's body, and persists as a mummy.

As expected, sows in the improved pens – whose stress levels were believed to be lower – had fewer piglets mummified than those in the conventional pens. In addition, the fact that fewer piglets were born dead from the improved pen sows indicates a smoother farrowing process, a possible consequence of lower chronic stress levels in late pregnancy.

Diarrhoea scores were also lower for piglets born to sows from improved pens.


An improved pen set-up, with rubber mats, natural rope and straw

ACKNOWLEDGEMENTS

We'd like to acknowledge Joanna Marchewka (IGAB PAS), who supervised this work. We'd also like to thank the farm owner and staff at the Ballylough Piggeries for facilitating our work.

Highlighting the link between housing and welfare

Our researchers' study confirms that good welfare acts like a preventative medicine for health conditions in both sows and their offspring, and offers additional benefits to sow reproductive performance. The improvements implemented to pen design are easy to install on typical commercial farms in Ireland, and as such are easily transferrable to commercial situations.

These findings are crucial in improving the sustainability of pig production and in addressing the grand global challenges of antimicrobial resistance, and offer important information on an area in which previously little was known. T

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"It's hard to be green, when in the red"

Farmers are facing a big challenge when it comes to balancing economic sustainability with environmental sustainability.

Words by: Michael Hayden, Assistant Professor of Accounting at Maynooth University

The economic importance of Ireland's agricultural industry is well documented. According to the Department of Agriculture, Food and the Marine, agriculture accounted for 9.5% (€14.5 billion) of total exports in 2019, and makes a significant contribution to employment in rural areas.

However, from an environmental perspective, the outlook is much less positive. Agriculture generates a high level of CO_2 emissions, and there is disagreement on how to tackle this.

The difficulty for farmers to balance economic sustainability with environmental sustainability is eloquently captured by the industry phrase: 'It's hard to be green, when in the red'. The challenge needs to be met, however, so farmers must work in collaboration with agricultural advisors and rural accountants to create more sustainable farm enterprises.

The complicated picture of sustainability in agriculture

The green agenda is at the forefront of national and international policy development in agriculture. Internationally, this is primarily driven by the UN's Sustainable Development Goals, as many of them relate to food production.

At an EU level, the European Green Deal, through its Farm to Fork Strategy, sets out plans to improve the environmental impact of the agricultural industry by incorporating them into policy development through common agricultural policy (CAP) reform.

At a national level, the Irish government has announced the introduction of the 2021 Climate Action and Low Carbon Development Bill, which includes ambitious targets to reduce environmental emissions in agriculture.

7.1%

Agriculture accounts for 7.1% of total employment in Ireland's rural areas

In contrast, economic sustainability in agriculture is primarily concerned with the long-term financial benefits of food producers. Many farm enterprises in Ireland are financially vulnerable, with a high reliance on subsidies to provide financial support. This is particularly the case for beef, sheep and tillage farmers.

The 2021 Irish Farm Report, published by expert accountancy and financial advisory group IFAC Accountants, reports that 87% of beef farmers, 75% of sheep farmers and 63% of tillage farmers acknowledge that their farm enterprise does not provide an adequate income.

With rising costs of farm inputs, such as fuel, fertiliser and feed, placing additional pressure on profit margins for food producers, the outlook for 2022 farm incomes is bleak. Recent events such as the Covid-19 pandemic and the war in Ukraine have also increased the complexity of this situation, placing renewed focus on the necessity of having a sustainable food supply.

Creating sustainable farm enterprises

Research shows that agricultural advisors and rural accountants are trusted primary advice sources for farmers and small business owners. Therefore, farmers need to work with them to learn about sustainability initiatives that can help them to improve both environmental and economic sustainability.

Agricultural advisors and accountants can assist farmers in conducting a cost-benefit analysis of environmental sustainability initiatives (for example, calculating the payback or return on investment of initiatives that reduce the carbon footprint of farm enterprises), and help business owners to take advantage of financial support that will allow them to meet the cost of such initiatives.

If we want to maintain a sustainable food supply, economic sustainability should not be sacrificed for environmental sustainability. Instead, the focus should be on educating farmers and changing work practices to meet the dual agenda of economic and environmental sustainability. T

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In real time

Teagasc is working with Spain's University of Córdoba and Ireland's leading dairy company Glanbia Ireland to evaluate a state-of-the-art process sensor for the real-time measurement of protein in milk protein concentrate.

Milk protein concentrate (MPC) powder is a high-protein dairy ingredient, often used in the production of protein-fortified foods, weight management, baby formula and sports and fitness products.

In the production of MPC powder, monitoring and the prediction of key compositional components such as protein content is essential after ultrafiltration, to ensure an optimal process is achieved.

An increase in global demand for dairy products is driving Irish dairy processors to optimise processes and therefore increase product throughput to meet this demand. Inline and real-time measurements have been proven to be beneficial for ensuring the target protein set for the process is closely achieved.

A project titled "NIR4Dairy" is being led by Teagasc in collaboration with University of Córdoba (Spain) and leading dairy company Glanbia Ireland, to evaluate near-infrared (NIR) spectroscopy as a process analytical technology in combination with the development of a robust prediction model, for inline measurement of protein content in liquid MPC.

Predicting protein content

NIR spectroscopy studies the interactions

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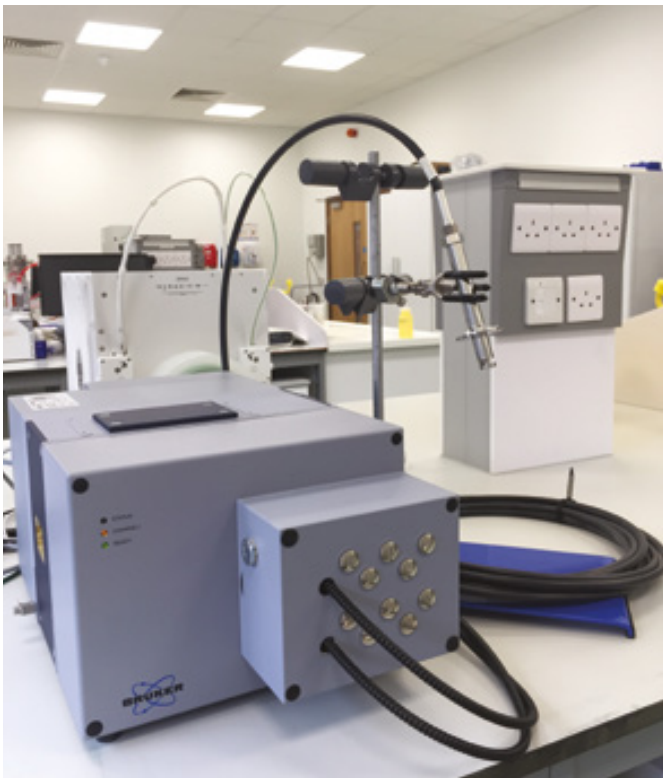

Near-infrared (NIR) spectroscopy technology

Flow test skid

between incident light and the sample. 'Spectral fingerprints' are generated that contain information from the sample that can be linked to its chemical components, such as protein, total solids and fat. This information is then used as part of building a predictive model.

Since the 1970s, NIR has been utilised in the dairy industry as a laboratory analytical method (offline) for analysis of compositional components. Recent advances in NIR technology and instrumentation have widened its application to online and inline continuous process monitoring.

Optimal prediction models rely on high-quality spectra and reference data. As a preliminary study, an NIR sensor was investigated using laboratory conditions to optimise optical settings (i.e. spectral resolution, scans per sample, spectra repeatability). Using the correct optical settings can ensure high-quality spectra are obtained from the product.

A laboratory model was developed by Teagasc researchers to predict the protein content of liquid MPC, using 120 representative MPC samples provided by Glanbia Ireland.

The NIR sensor was also tested in pilot scale studies using a flow test skid at Teagasc's Bio-functional Food Engineering (BFE) facility. This was to investigate the effect of process conditions such as temperature and flow rate on the spectra quality and model performance.

Giving dairy processors better control

The results of the studies showed that the use of NIR sensors for the inline measurement of protein was effective and would allow dairy processors to make timely decisions regarding adjustments for process optimisation.

By integrating the prediction model developed using an NIR sensor with a process management system, dairy processors will have better control of their processes. The NIR sensing technology is a fast, non-destructive and chemical-free method and, based on the success of the laboratory model and pilot scale studies, it has been installed at the industry partner's MPC process plant.

Ongoing work in this project is required, including to optimise optical settings for continuous collection of MPC spectra using real-life process conditions, and conduct experimental trials to update the laboratory protein model and validate the model performance at industry scale.

The project researchers have made significant advancements in the area of NIR application and dairy processing so far, and have shown the potential that this technology can help to minimise out-of-specification batches whilst also reducing extra protein give-away in the final powder. T

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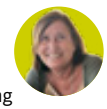

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Teagasc researchers are working with partners to investigate the use of plant proteins in the controlled release of bioactive compounds during digestion.

You are what you eat

The statement 'You are what you eat' is well-known in food science. It refers directly to the bioactive compounds that we ingest when we eat healthy foods, and how much of them our bodies absorb.

Bioactive compounds are substances that have a biological activity, such as omega-3 fatty acids and flavonoids (found in fruit and vegetables).

They are important, as they have essential functions for maintaining human health. For example, omega-3 fatty acids help to reduce the risk of coronary disease and is a precursor of anti-inflammatory mediators. Quercetin – one of the most abundant flavonoids – has several health benefits, such as antioxidant, anti-inflammatory and anti-obesity properties.

However, the absorption of these compounds by the organism in which it has entered into depends on many factors, including its physical and chemical characteristics and the structure of food, often referred to as the food matrix. In addition, most bioactive compounds have limited accessibility to the organism, making their ingestion more challenging.

In collaboration with Germany's Technical University of Berlin (TUB) and microencapsulation experts EncapProcess, France, Teagasc researchers are investigating how to improve the bioaccessibility and bioavailability of omega-3 fatty acids when ingested as a small capsule, using a combination of plant proteins and polysaccharides (the most abundant carbohydrate found in food) as the delivery material.

The benefits of pea protein

Encapsulation is a coating technique in which biopolymers surround bioactive compounds to protect them against external factors such as oxygen, light and moisture, and promote their controlled release when ingested. This method (known as complex coacervation) consists of forming a delivery structure (microcapsule) through the electrostatic interaction of two biopolymers.

Talita Comunian, Marie Skłodowska-Curie Fellow, Research Leaders 2025 Fellow and project lead, says: "Previously, the main biopolymers used as carrier materials for complex coacervation were animal and dairy proteins and polysaccharides. In recent years, however, many of these proteins have been replaced due to dietary restrictions, food allergies and consumers' preferences.

"Pea protein is considered a promising plant protein alternative, due to its low cost, wide availability and excellent amino acid profile. Gum arabic – a natural tree gum and polysaccharide – is also widely used by the food industry as an encapsulating material, as it has low cost, broad availability and good emulsifier properties."

Did you know?

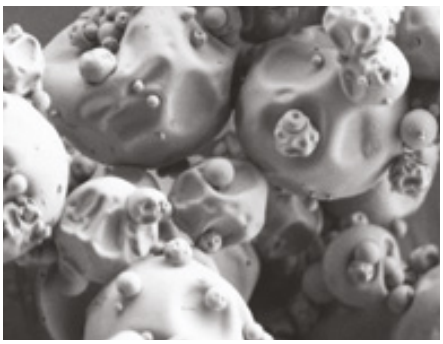
Humans can prevent various health problems by consuming the recommended daily allowance of bioactive compounds.

The best conditions for creating microcapsules

The complex coacervation process is carried out in an aqueous solution, therefore a drying step is necessary for feasible handling and food application of the microcapsules. There are many drying techniques, but spray-drying is the most widely used method in the food industry, due to its low cost and simplicity. Spray-drying consists of the atomisation of the sample using hot air at a specific temperature and pressure.

Electrospraying is also a promising technique for encapsulation; it is similar to spray-drying but doesn't require a high temperature, and the drying is performed with the application of voltage.

As part of her research, Talita analysed



Scanning electron micrograph of spray-dried microcapsules

Sources of bioactive compounds that help to maintain health:

OMEGA-3
- Fish
- Chia seeds
- Flaxseed oil

QUERCETIN
- Onions
- Apples
- Broccoli
- Tea
- Red wine

the best conditions for forming the microcapsules.

"The microcapsules were dried by both spray- and electrospray-drying," she says, "with the help of colleagues at the University of Nantes and spray nozzle technology experts Fluid Air, respectively.

"The results were interesting. The different drying methods promoted the formation of different particles and, consequently, different behaviour for the protection and release of encapsulated compounds."

A plant-based future

Because the digestion of bioactive compounds depends on the food matrix in which these compounds are incorporated, the researchers are investigating the incorporation of these microcapsules into different food products. They are also investigating the *in vitro* digestion of these compounds, when encapsulated and in their free form.

Besides the use of plant proteins for the protection of bioactive compounds, an innovation of this project is the investigation of controlled release during *in vitro* gastro-intestinal digestion. Since microcapsules obtained by complex coacervation are stable at low pHs, the researchers expect the compounds to be released and digested mainly during the intestinal phase.

"What this study shows is that pea protein could be a viable alternative to animal and dairy proteins as a carrier material for complex coacervation," says Talita.

ACKNOWLEDGEMENTS

We would like to thank Laura Gómez-Mascaraque (Teagasc), Audrey Maudhuit (Fluid Air) and Guillaume Roelens (University of Nantes) for their collaboration on this project.

"Furthermore, this is the first step towards developing a structured delivery system with pea protein and gum arabic, for the encapsulation of bioactive compounds, with a controlled release of omega-3 fatty acids and quercetin." T

FUNDING

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Weed watch

Teagasc researchers have brought easy-to-use technology into the field, by developing a successful data collection mobile app. This app is supporting a long-running project promoting the wider adoption of sustainable conservation tillage systems on Irish farms.

ECT Weed Watch allows for the easy tracking of samples

Conservation tillage (CT) is a non-plough-based crop establishment technique that, combined with other measures, can improve soil quality and properties over time and reduce tillage costs. Despite its benefits, it has not been widely adopted across Ireland. This is because CT practices can enable the rapid spread of grass weeds, which in turn reduce crop yields and can lead to total crop failures.

Teagasc's Enable Conservation Tillage (ECT) project has spent the last few years investigating and offering sustainable, cultural and chemical control solutions and support tools to stop the prevalence of grass weeds on farms. As part of this, members of the project team have created ECT Weed Watch – a unique mobile field app that enables the accurate recording of data at precise locations.

Here, former ECT Technician David Schilder, former ECT Project Advisor Jimmy Staples, Spatial Analysis Unit Senior Researcher Réamonn Fealy and current ECT Project Manager John Mahon share why they created ECT Weed Watch, and the impact it has had so far.

How many farms are involved in the ECT project?

John Mahon: There are 10 'focus farms' involved directly with the project, each with its own crop establishment technique. Our project team advises farms using CT on different methods to help overcome grass weed issues, and then monitors the CT practices and their impact on grass weeds.

The aim of the project is to allow farmers in the tillage industry to adopt CT establishment practices for the long-term sustainability and viability of their farming enterprise.

How engaged have farmers been in the project?

David Schilder: We conducted a large survey of growers across the tillage industry in 2020 and 2021. With the help of Teagasc advisors, Biodiversity Agriculture Soil Environment (BASE) Ireland, industry and professional tillage advisors, over the two years we managed to get more than 120 farmers involved. They were curious about what we were doing and happy to take part.

Jimmy Staples: Through holding events and workshops, we've helped to raise awareness and inform the industry of how to identify grass weeds in field, control an infestation and eradicate the problem. The level of interaction and interest displayed by attendees was emphatic.

What led to the development of the ECT Weed Watch app?

David: As I mentioned previously, we conducted a survey across the tillage regions of Ireland. The aim of this was to establish how on-farm management factors drive grass weed populations, to identify and assess grass weed levels on farms and to test grass weeds for herbicide resistance.

Due to the seasonal effects of grass weed prevalence in crops, the survey was done over two years, and required the same two fields on each surveyed farm, in order to have repeat assessments.

We needed a way to accurately return to the same survey points in each of the fields, so we developed the ECT Weed Watch app – a location-based tool that allows for the easy tracking of samples.

How does the app work?

Jimmy: The app enables all data collected by the ECT team and Teagasc tillage advisors to be accurately recorded at a precise location and in a standardised format. It makes gathering data more accurate and enabled the project team to achieve a larger survey sample without compromising the quality of the data collected.

Réamonn Fealy: There are two particular benefits to the approach we took in designing the app. First, as David already outlined, is the capacity for repeat visits to a single point with high accuracy. Second is that standardised data can be viewed in real time if required.

What was the design approach for the app?

Réamonn: We built the app using a forms-based field collection tool known as Survey123, from ESRI Inc.. It runs on mobile devices and integrates seamlessly with AGOL, a cloud-based Geographic Information System (GIS) technology that creates, analyses and maps all types of data.

GIS is a core technology used in Teagasc's

L-R David Schilder, Réamonn Fealy and John Mahon review data gathered using the ECT Weed Watch app

Spatial Analysis Unit. AGOL has been instrumental to the development of the app and is, to my mind, a game changer for the rapid development and deployment of location-based field recording tools.

Jimmy: The project team sat down with Réamonn and ESRI Ireland (the company that supplies the underlying technology and who helped in the design of the Survey123 app), and discussed the important data required from the field assessments.

A plan was drawn up that allowed the capabilities of the app to work in tandem with the data we needed to record. After a few meetings, we had developed a prototype which worked well. Following further small adjustments, ECT Weed Watch was created.

What has the feedback about the app been?

David: It's been very positive. Team members who have used the app find it to be very functional and easy to use once shown how to. It saves time in the field as it only takes a few minutes to fill out each survey point.

Some users even think it may be beneficial to other projects to adopt such technology for on-farm assessments or research projects within Teagasc.

What's next for the ECT project?

John: We're currently analysing the entire survey data collected using ECT Weed Watch, with an aim to publish a paper in autumn 2022. We're also using the app to continue carrying out studies on different grass samples to assess resistance levels.

The project is due to end in 2023. By then, we hope to have practical management tools for grass weed identification and integrated weed management available for the tillage industry. A lot has been achieved through this project already, largely thanks to the strong communication between the project team, farmers and advisors. T

FUNDING

The Enable Conservation Tillage (ECT) Project is a European Innovation Partnership (EIP) funded by the Department of Agriculture, Food and the Marine.

In good company

What did developing an app teach you?

David: I was surprised by how easy it was to customise and design our own unique app. It really was a treat to be able to leave the pen and paper at home.

Réamonn: It was a fantastic example of the potential collaboration that GIS technology can facilitate. We were able to produce an app that met the ECT project team's needs, all without meeting in person!

Jimmy: With the right team and a bit of flexibility and endeavour, a solution can be found to just about any challenge!

Under the spotlight: a public view of animal welfare

Whilst perceptions of farm animal welfare are generally positive among consumers on the island of Ireland, there is a need to address gaps in information and sector differences.

Societal attention towards farm animal welfare is increasing and having an impact on consumer behaviour. To get a better understanding of the public's knowledge and opinions on this topic, researchers from Teagasc carried out fieldwork across the island of Ireland, as part of the Surveillance Welfare and Biosecurity of farmed animals (SWAB) project.

Capturing public sentiment

The project team ran focus groups and a survey in which almost 1,000 members of the public participated. As demonstrated in Figure 1 (page 21), this fieldwork revealed generally positive public sentiment about welfare standards on Irish and Northern Irish farms in the dairy, beef, pork and poultry sectors.

However, the results do show variation in perceived welfare conditions across sectors. Greater concerns arise for welfare in poultry and pork production, whilst lower concerns appear for dairy and beef.

These sectoral differences are explained through a number of factors that consumers tend to use to assess welfare conditions. On the island of Ireland, cows and cattle are viewed by the public to be part of a pasture-based, extensive system with high public visibility resulting in positive perceptions of welfare. Conversely, poultry and pig farms are viewed as intensive, having low public visibility with issues relating to housing and outdoor access.

Across all sectors, however, the survey also showed that the public feel that welfare conditions have improved over the last ten years. At the same time, both the survey and the focus groups showed the public feels uninformed about farming practices and welfare-friendly foods, and that they are eager to seek out additional information.

From concerned citizen to conscientious consumer

Research shows a gap often exists between the concerns of citizens and the translation into shopping behaviour as a consumer. Advanced analysis of the survey data by the project team shed further light on this citizen-consumer disconnect.

Using a form of analysis to group participants based on their responses to various attitudinal questions, three profiles

Labelling can communicate welfare information and lessen the gap between consumers and farmers

Figure 1. Public perceptions of farm animal welfare on the island of Ireland (n = 972)

of typical consumers were identified: 'indifferent', 'engaged' and 'struggling'.

The 'indifferent' consumer (69.1% of participants) had positive perceptions of farm animal welfare on the island of Ireland. But whilst they feel motivated to buy welfare-friendly produce, this attitude is less likely to translate to frequent purchasing behaviour.

The 'engaged' consumer (16.5% of participants) is highly concerned about welfare standards in farming, and is highly motivated to purchase welfare-friendly produce. Unlike the 'indifferent' consumer, this motivation translates to frequent purchasing behaviour.

The 'struggling' consumer (14.4% of participants) is also concerned about welfare standards on farms. But whilst they're motivated to purchase welfare-friendly produce, this motivation doesn't translate to behaviour. A lack of choice, dearth of information, inadequate availability and difficulty using relevant labels represent significant hurdles for this type of consumer. Such consumers will need to be adequately supported through interventions focused on enablement, such as the establishment of widely accessible and trusted front-of-pack labelling for welfare-friendly produce.

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FUNDING

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Addressing public information gaps

Labelling can serve as an important platform for communicating welfare information and lessening the gap between consumers and farmers. However, as the public becomes more exposed to different forms of information through online and social media, there is intense scrutiny of labels: what they say, what they mean and how much they can be trusted.

Any labelling scheme must be underpinned by a transparent and evidence-based quality assurance scheme to build public trust. Public engagement efforts, which seek to not only educate but also empower the public with information on farming and food production, will also be a vital strand required to support any future labelling strategies related to welfare practices.

As consumers self-report low knowledge on the subject of welfare and farming practices, it is evident that a vacuum of information exists relating to food production and farm animal welfare. This, alongside the lack of awareness shown about hot topic welfare issues being discussed in the agricultural sector, is contributing to the consumer disconnect.

Following on from the fieldwork with the public, work was carried out to tackle some of the information needs arising. A co-design approach was undertaken with public engagement and communication experts, animal health and welfare scientists, policy-makers and graphic designers, to design an animated whiteboard video aimed at the public.

The content of the video is about good welfare practices on Irish dairy farms. The information aims to break the citizen-consumer disconnect by empowering people with knowledge about what good farming practices look like. By being better informed about farm animal welfare and what that entails in terms of farming practices, consumers can make better choices. T

You can watch the video by visiting youtube.com/watch?v=FodFmEuOVaY.

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Protected urea:

a benefit for farmers and the environment

Switching to the right type of fertiliser can allow farmers to maintain grass growth whilst minimising damage to the environment.

To feed the world's growing population, nitrogen fertilisers are frequently applied to soil to achieve high grass growth and production. Nitrogen fertilisers are a major contributor to ammonia and greenhouse gas (GHG) emissions, however, and pressure is increasing for farmers to reduce the environmental impact of agriculture.

The main emissions from the application of nitrogen fertiliser are the release of ammonia when urea-based fertilisers are used, and nitrous oxide when calcium ammonium nitrate (CAN) based fertilisers are used. When urea is applied to soils, approximately 15.5% is converted to ammonia and volatised (converted into a gas) to the atmosphere.

To reduce ammonia emissions, nitrogen stabilisers such as urease inhibitors have been developed. Nitrogen stabilisers are compounds that block the reaction site on the urea granule, reducing ammonia volatilisation by 79.5% compared to ordinary

Urea made with nitrogen stabilisers is known as 'protected urea' (pictured). It reduces ammonia emissions when compared to standard urea

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urea, and nitrous oxide emissions by 71% compared to CAN. Urea made with nitrogen stabilisers is known as 'protected urea'.

The environmental benefits of changing fertiliser type have been proven, but there are questions regarding the efficiency of protected urea in terms of grass growth and dry matter (DM) production. To address these questions, researchers from Teagasc set up an experiment to compare the performance of different fertiliser types on grass growth.

Experimenting with fertilisers

Grazing plots were set up at four locations across Ireland, comparing the grass growth of three fertiliser types: CAN, standard urea and protected urea containing the urease inhibitor NBPT. Each plot had two fertiliser rates – 150kg nitrogen (N)/ha per year and 250kg N/ha per year – giving a total of six treatments.

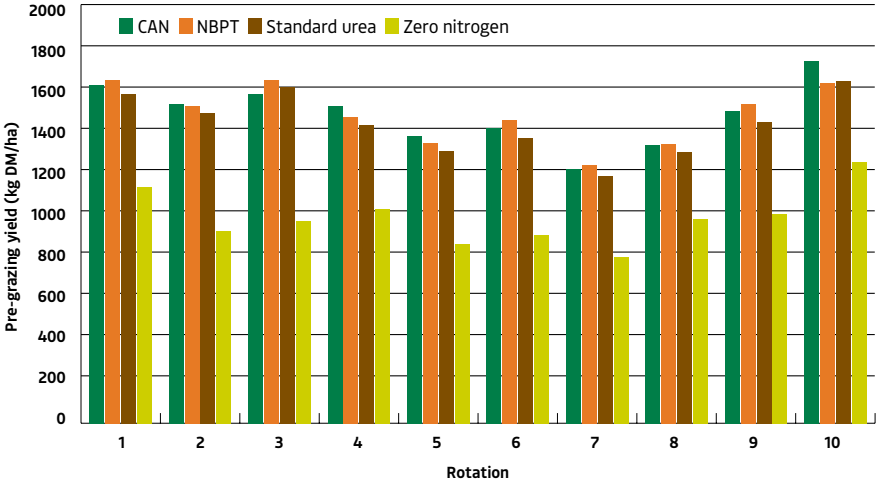
In 2019, the study began in Cork with the first two sites: Teagasc Moorepark and Clonakilty Agricultural College. In 2020, Ballyhaise Agricultural College in Cavan and Mellows Campus in Athenry, Galway, were added. Plots with zero nitrogen were added at each site in 2020, and the study ran until the end of 2021.

The Athenry site was grazed with sheep, whereas the remaining three sites were grazed with lactating dairy cows. At each site, the first grazing occurred in March, six weeks after the first nitrogen application, and thereafter when the CAN 250kg N/ha treatment had a pre-grazing herbage yield of approximately 1,500kg of DM/ha. The study had a target of ten rounds of grazing in each year.

Fertiliser applications were applied after each grazing event: the 150kg N/ha sub-treatment received 60% of the fertiliser rate that the 250kg N/ha sub-treatment received for all fertiliser applications. Plots also received sulphur, phosphorus and potassium during the main grazing season, to ensure other macronutrients were not limiting. All sites were at a sufficient pH level for grass production.

At each grazing event, measurements of pre- and post-grazing height were recorded, as well as pre-grazing yield (Figure 1). A sample of grass was also collected from each plot to measure dry matter, crude protein, water soluble carbohydrates (WSC) and dry matter digestibility contents.

Figure 1. Seasonal responses in pre-grazing herbage yield to nitrogen fertiliser type



The impact of protected urea on production

Over the course of the study, an overall benefit was detected from using urea protected with NBPT versus standard urea. CAN and the protected urea grew 13,478kg and 13,542kg DM/ha respectively. This was nearly 500kg DM/ha greater grass production than urea.

As Figure 1 shows, the average pre-grazing yields for the three fertiliser types were 1,485kg DM/ha for CAN; 1,480kg DM/ha for protected urea; and 1,436kg DM/ha for standard urea. Similar grass production was observed for the CAN and protected urea under grazing conditions at all sites, providing further evidence of the reliability of urea combined with NBPT.

Given these comprehensive findings from multiple sites over a number of years, farmers and industry can confidently believe that urea protected with NBPT will reliably deliver herbage yields that match CAN and exceeds standard urea yield, whilst limiting harm to the environment. T

98%
Agriculture accounts for 98% of total ammonia emissions and 37% of total greenhouse gas emissions in Ireland.

10.6%
of Ireland's ammonia and greenhouse gas emissions comes from nitrogen fertilisers.

2030
The Irish Government has set a target to reduce agricultural greenhouse gas emissions by 22-30% by 2030, compared to 2018 levels.

84%
Calcium ammonium nitrate accounts for 84% of the straight nitrogen market in Ireland, compared to other grass growing regions where urea accounts for the greatest proportion.

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Mitigating methane on farms

Principal Research Scientist Sinéad Waters is leading research at Teagasc to develop farm-ready technologies that will reduce enteric methane emissions – a major source of greenhouse gas emissions.

Principal Research Scientist Sinéad Waters is looking for ways to reduce enteric methane emissions

During the digestive process, ruminants (mammals with multiple stomachs, such as cattle and sheep) emit enteric methane – a greenhouse gas (GHG) that occurs in the intestines. These enteric methane emissions are a significant contributor to agriculture's GHG output and, as such, there is an urgent need to reduce them.

Feed additives have proven to be effective in mitigating enteric methane emissions without compromising animal performance. However, EU and Irish regulations require the passing of rigorous processes in order for supplements to be approved for commercial use.

To support this, Teagasc's Animal & Bioscience Research Department is conducting studies and trials to develop and assess safe feed additives such as Bovaer (3-NOP), seaweed and their extracts, halides and oils.

The project – named *METH-ABATE* and funded by the Department of Agriculture, Food and the Marine – is focusing on

feed additives' ability to reduce methane emissions in beef, sheep and dairy, as well as its effects on productivity and end-product quality.

The research is being led by Principal Research Officer Sinéad Waters. Sinéad has a PhD in gut microbiology, and during a postdoctoral role in the same area, gained specialist experience in rumen microbiology.

She joined Teagasc in 2005 as a contract research officer working in molecular biology. In 2007, she was subsequently the first person appointed into the Animal & Bioscience Research Department, moving into the area of rumen microbiology, where she has remained since.

How prominently is methane emission reduction being investigated in industry?

The issue of methane emissions is a big problem internationally, so there's lots of ongoing work to establish and identify successful feed additives. Research is predominantly focused on indoor systems – which are more commonly found in other countries – but in Ireland we're mainly pasture-based. As such, our focus is to generate feed additives that can be developed for outdoor systems.

What's novel about the work you're doing through the METHABATE project?

The industry partners and universities we're working with are developing some novel feed additives, and we're also trying to develop slow-release formulations, which will be important for use in pasture-based systems as they prevent the need for continuous delivery.

Furthermore, we'll be keeping consumers in mind and monitoring if these solutions have any negative implications for meat and milk quality. Overall, we're taking a holistic approach, incorporating life cycle and cost analyses.

What methods have you been using to carry out your research?

We carry out *in vitro* studies in the lab using an artificial rumen system known as RUSITEC. This system allows us to screen feed additives without having to invest in expensive large animal trials. Animal trials are performed only if the additives are successful, and initially only using sheep (they're easier to handle and cheaper). Following further success, we then carry out trials on cattle.

During these trials we measure methane and sample the rumen contents to study their microbes. Using sequencing and bioinformatics approaches, we can see what the feed additives do to the microbes in the rumen – which are critical to digestion and methane production. We want to make sure the additives have no negative impacts on digestion, but that they do reduce methane emissions.

In my immediate team and helping me to complete this work is Head of Animal & Bioscience Department David Kenny, postdocs Stuart Kirwan and Paul Smith and PhD students Emily Roskam and Caroline O'Donnell. We're also supported by colleagues in other Teagasc centres and universities.

What results have you seen so far from your research?

We began the project in 2020, and in that time, we've managed to complete a lot of *in vitro* studies, a large sheep trial and a beef trial. We've found some promising candidate additives, but work is still in progress. We have more trials set to commence in summer 2022, which will offer further insights.

What are some of the challenges related to this project?

It's a challenge in itself to develop a successful feed additive with effects that will persist when applied at pasture. Rumen microbes are very resistant to change, so the feed additive will have to be very targeted. Bovaer is effective for this, but it doesn't offer a slow release option at present.

Slow release can be an encapsulated form of the additive that can be given to grazing cattle once and then released in pulses over a long period of time, avoiding the need for continuous delivery. This is especially important for pasture-based systems, as the feed additive needs to be present in the rumen when the feed is being digested, to block the production of methane.

Cost is another challenge – margins in beef production are already very tight; if there's no added benefits to production, then incorporating feed additive costs will be difficult.

How have farmers responded to your work?

Discussion groups with farmers have been promising. They're interested to learn more and happy to hear of prospects of solutions. This doesn't guarantee uptake, however, and there's also a possibility that consumers won't like the idea of additives being used to produce their meat and milk.

Education on this topic is essential, and we want information to be made widely available.

You presented at COP26 and discussed Ireland's work in methane reduction – how was the experience for you?

It was great! The event I presented at was designed to bring experts together to see how we can have a sustainable livestock system globally. I was invited onto the panel due to my role as co-chair of the Global Research Alliance's Livestock Research Group, and it gave me an international platform to discuss Ireland's strategies on reducing emissions. Other countries are also trying to develop similar strategies, so it was a good networking opportunity.

We had lots of positive responses from that panel, including from the Irish government, and it was a great opportunity to raise awareness of the crucial role livestock systems play in feeding the world. T

Up close and personal

What's your favourite animal?
Dogs and cattle – we have a German pointer and Charolaise beef cattle at home!

If you hadn't ended up in agriculture, what other job would you have wanted to give a go?
I love science and studied Biotechnology at university, so could happily have worked in a laboratory as a medical scientist.

What are you most proud of professionally?
I really value being part of international groups such as the Global Research Alliance and the European Commission's expert group on methane emissions, as they allow me to represent Ireland in international discussions. Fundamentally, I want to contribute to finding a solution to reducing GHG emissions within agriculture, and these are great opportunities to do that.

Some *hebe* shrubs produce long leafy stems with large glossy green leaves

Hebe 2.0

A novel *Hebe* shrub developed by researchers at Teagasc has the potential to be a new candidate crop for the growing cut foliage sector.

Hebe, a genus of plants, are evergreen shrubs that produce flowers. Some *Hebe* shrubs, however, produce long leafy stems with large glossy green leaves. One such species is *Hebe speciosa*, which provides uniquely different characteristics to current offerings in the cut foliage trade.

With its long sturdy stems and plentiful large leaves in the upper portion, these *Hebe* shrubs offer an alternative leaf form to use in floral bouquets and flower arranging. They also produce fewer flowers than most *Hebe* cultivars – an advantage for a cut foliage plant, in which the leafy foliage is prized.

A few years ago, a block of *Hebe speciosa* plants was established at a grower-owned site in Tralee, County Kerry, to evaluate it as a potential cut foliage species. After several years it was confirmed to be a variety of definite interest to the sector, but it still wasn't a perfect fit.

Andy Whelton, Teagasc Specialist Advisor to the cut foliage sector, explains: "Feedback from florists and foliage processing companies indicated that the leafy *Hebe* stems needed to be more robust to meet the demanding requirements of the market place."

Further research was therefore needed to explore the possibility of enhancing the plant's characteristics from a cut foliage perspective, using plant breeding techniques.

Plant breeding for new varieties

Plants normally contain two sets of chromosomes in their cells – one from each

A block of *Hebe speciosa* plants was established at a grower-owned site in Tralee, County Kerry

parent – known as 'diploids'. In nature, plants can sometimes spontaneously double the number of chromosomes in their cells, to become 'tetraploids' or 'polyploids' if there are multiple copies.

Polyploidy is an advantageous trait in many food crops, such as wheat and potatoes, as plants with multiple copies of chromosomes are often bigger and more vigorous. Polyploids can also be produced in the laboratory using chemicals like colchicine and oryzalin, and this technique has been used extensively in plant breeding for new varieties.

Farhana Afroze, Teagasc Post-Doctoral Researcher, says: "We conducted polyploidy experiments on *Hebe speciosa* to see if sturdier, non-flowering varieties could be generated. Sterile plantlets were needed for the polyploidy experiments, and these were prepared by micropropagation (a technique used to generate genetically identical plantlets) using fresh cuttings taken from the plants in Tralee."

Single nodal segments (the stem section between two sets of leaves) were taken and subjected to treatment by colchicine and oryzalin. Whilst the harsh chemical treatment killed many plants, around 46 (20%) of them survived. Ploidy levels were measured and a total of six plants were tetraploid, whilst 14 plants were mixoploids (featuring both diploid and tetraploid cells).

€7 million

The value of the foliage sector was worth €7million in 2020, and demand for high quality foliage continues to increase.

Differences in plant characteristics

All the surviving plantlets were grown in the greenhouse for six months and evaluated for novel factors that differed from the controls.

"Analysis of the tetraploids showed they had almost twice as many stems and branches as the controls," says Farhana. "Stem diameters were also thicker, leaf internodes (the distance between the leaves on the stems) were shorter and flowering was much reduced.

"Although there was not much difference in plant height after six months, the tetraploid stems were thicker and more abundant, with more branches and with larger, thicker leaves, making the tetraploids bushier and leafier than the original diploids."

Although the differences are small and subtle, this combination of factors makes the tetraploids a very interesting potential variety for cut foliage, as overall they would be quite productive plants with good stem and leaf characteristics.

Monitoring long-term results

The new polyploid plants have now been planted out for field and commercial evaluation.

Successful new varieties for the cut foliage sector need to clear many hurdles to demonstrate they are worthy for planting at commercial scale, and the novel traits of the tetraploids need to be stable over time and persist with continued cultivation. They also need to demonstrate characteristics such as a low pest and disease susceptibility, as well as be frost hardy in the Irish climate.

"It will take another few years of trials and evaluation to establish if the *Hebe* polyploids become a new fixture in the cut foliage offerings from Irish growers," concludes Andy, "but things are looking promising so far." T

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For hire:
the benefits of hired labour for family farms

Research undertaken by Teagasc and National University of Ireland, Galway shows that the use of hired labour on dairy farms is a beneficial strategy, yet it is currently underutilised.

Steps towards the abolishment of the milk quota began in 2008, and its final removal in 2015 has caused significant structural change within the European dairy sector. Between 2008 and 2021, the volume of milk produced in Ireland increased by over 75%. This expansion in production has led to an increased labour requirement, and the mismatch of increasing herd size and labour availability is a growing concern.

Family labour may temporarily relieve the shortage. However, the dramatic structural change being experienced will require additional non-family labour. The increased workload has already become a significant source of stress for Irish farmers, which is why researchers at Teagasc and National University of Ireland, Galway (NUI Galway) are exploring the role of hired labour on farms.

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Labour challenges on Irish dairy farms

The majority of Irish dairy farms are pasture-based, with a spring calving system. This gives the Irish dairy sector a comparative advantage in producing milk, but the downside of such a production system is its uneven demand for labour throughout the year.

Despite difficulties in sourcing farm labour, there is evidence that some farmers are reluctant to hire it. For instance, data from the 2018 Teagasc National Farm Survey (NFS) indicated that only 11% of dairy farmers planned to hire extra labour within the next five years. Despite the fact that 34% of dairy farmers planned to expand their production in the same time interval, only 7% of those respondents also intended to hire more labour.

Luis Garcia Covarrubias, a Teagasc Walsh Scholar working in the Agricultural Economics and Farm Surveys Department and PhD student at NUI Galway, is one of the researchers exploring hired labour on farms. He says: "This reluctance from farmers to hire labour may be driven by the belief that family labour is more suitable for the farm.

"At least two reasons may influence this. Firstly, the unfavourable weather conditions of 2018 resulted in a decline in average dairy farm income. And secondly, family labour share has been associated with higher levels of farm productivity."

> **Hiring labour is suitable for increasing efficiency on the farm, whilst also easing family workload.**

The benefits of hired labour on efficiency

The researchers estimated the average level of dairy farms' efficiency and the effect hired labour had on it, on the short-term, long-term and overall efficiency of Irish dairy farms.

The efficiency of farms is an economic concept that examines how well resources are allocated on a scale of 0 to 100%. Therefore, farms' efficiency is an index of doing things right. A positive impact of hired labour on efficiency would imply that it helps to improve efficiency, which suggests that hired labour is skilled.

"Our estimation of overall efficiency is 79%," says Luis. "This suggests that Irish dairy farms are highly efficient, which is consistent with previous industry findings on the efficiency of the Irish dairy sector.

"Additionally, short- and long-term efficiency is similar for all dairy farms, ▶

A deep dive into data

The researchers utilised a subsample of 939 dairy farms from the Teagasc National Farm Survey (NFS), spanning 2000 to 2018. Every year, a professional data team collects the data as part of the EU Farm Accountancy Data Network (FADN). In addition to standard farm accountancy measures, the Teagasc NFS also captures farm labour through self-reported hours and work units. Farm labour is divided into two categories: paid (hired labour) and unpaid (family labour).

Table 1 illustrates the average figures for hired labour on Irish dairy farms over the decade between 2008 (when quota removal was introduced) and 2018. It also shows the average for all the years examined.

The data indicates that Irish dairy farms utilised a yearly average of 520 hours of hired labour across the period examined. Average hired labour hours remained relatively stable from the quota elimination confirmation period in 2008 to its execution in 2015. This figure then increased significantly in 2018, to an average of 739 hours. This increase is understandable given the strong growth in milk production experienced following the removal of the quota.

Across all the years examined, farms that hired labour reported just 0.43 work units. The figure increased to 0.55 in 2018. Around 38% of farms did not hire labour in the period, and this figure fell slightly lower in 2018 at 36%. Hired labour represents 11% and 14% of the total labour hours over the period and in 2018 respectively.

The above figures emphasise the prevalence of family farming in an Irish context. And they show that, despite the increase in 2018, the proportion of farms utilising hired labour remains relatively low.

Table 1. Hired labour on Irish dairy farms between 2008 and 2018

Time period	Number of farms sampled	Mean hours worked by hired labour*	Hired labour in annual work units**	Farms with no hired labour	Hired labour in total labour share
2008	362	534.85 (794.3)	0.44	38.39%	11.44%
2015	335	511.09 (756.42)	0.41	34.62%	11.47%
2018	325	738.91 (979.52)	0.55	36%	14.1%
All years	390	520.5 (796.21)	0.43	37.93%	11.13%

Standard deviation in parentheses
***One work unit represents 1,800 hours a year. People aged under 18 are allocated the following work unit equivalent: 16 to 18 years = 0.75 work unit and 14 to 16 years = 0.50 work unit.*

Source: Teagasc National Farm Survey data

which suggests that Irish farmers respond efficiently to short- and long-term events."

The researchers also observed that the efficiency of the Irish dairy sector has had an increasing trend in recent years (i.e. from 2008 onwards). This rising trend is particularly evident post-quota abolition in 2015. However, a dip was observed in farms' efficiency in 2018, related to adverse weather events and the subsequent impact on production and costs.

Interestingly, the analysis indicates that relatively smaller farms (i.e. those with less than 80 cows) benefit more from hiring labour.

Luis explains: "Previous industry research has found that smaller farms have a lower hired labour share and are generally less efficient. Therefore, it is easier to increase efficiency on these farms.

"Furthermore, our findings suggest that the effect of hired labour decreases slightly as herd size expands. That's because, intuitively, as herd size grows, so too does total labour input. This growth increases the need for additional hired labour and thus total labour costs.

"It is generally accepted that expanding farms need additional hired labour to manage the increasing workload. As such, it is not sustainable in the long term for farmer and family labour to absorb the extra workload."

The analysis confirms that larger and expanding farms should utilise hired labour if available, but the positive effect of hired labour on efficiency is larger for smaller and non-expanding farms.

Supporting the use of hired labour on farms

The findings imply that policy should expand programmes that ease access to hired labour

The proportion of farms utilising hired labour remains relatively low

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for all farms. This is important as many dairy farmers may still be reluctant to hire additional labour. The message that hired labour assists in improving farm efficiency can be conveyed through extension agents such as Teagasc, Farm Relief Services and the Macra Land Mobility Service programmes.

Luis says: "Our findings should give farmers confidence that hired labour is a win-win situation. It is suitable for increasing efficiency on the farm, whilst also easing family workload."

However, whilst the analysis indicates a positive effect of hired labour on farms' efficiency, the result is small in economic terms. For instance, an extra work unit of hired labour assists in increasing efficiency by 1.5% on average.

"To further increase the efficiency of farms, it is not enough to delegate part of the workload to hired labour," concludes Luis. "Instead, it is necessary to continue adopting new technology and techniques.

"Our analysis does not distinguish between the specific work tasks executed by hired labour. Therefore, the allocation of hired labour on specific farm activities and its influence on farms' efficiency is a clear direction for future research." T

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Getting to know

Dilip Rai

Senior Research Officer **Dilip Rai** has worked at Teagasc since 2009, and currently leads a research team in the field of novel food ingredients. Here, he shares with us how he ended up at Teagasc, and where he can be found outside of work.

What's one of your earliest memories with science?

I grew up in Bhutan, South Asia, and I can recall always being fascinated with the wonders of science since my primary school days. We were taught from a book titled *Science is Fun*, and for me, it was!

Where did that passion for science take you?

I actually moved to Ireland to complete my undergraduate degree in Applied Sciences at what is now the Technological University Dublin. I then briefly returned home to Bhutan.

What convinced you to return to Ireland?

The friendly people with a great sense of humour, and the beautiful greenery. But it didn't stop me moving temporarily elsewhere. I did my PhD in Medical Biochemistry at the Karolinska Institute in Stockholm, Sweden.

How did you end up at Teagasc

Following my PhD, I continued to work at the Karolinska Institute as a post-doctoral researcher, focusing on biologically active proteins. I then took the opportunity to head back to Ireland and work in the Centre for Synthesis and Chemical Biology at University College Dublin (UCD). I've held an adjunct Assistant Professorship position there since 2009 – the same year I moved to Teagasc, where I've stayed ever since.

My research interest is on the study of natural products present in food, to understand their role in controlling biological processes. The hope is that this research can support the delivery of a sustainable food chain, with positive impacts on human and animal health.

Outside of work, where do your interests lie?

I'm a football coach, training children under 10 at my local Kilcock Celtic Football Club two evenings a week. I also like writing poems, proses and very factual short stories.

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Celebrating CELUP

Identifying the contribution of Teagasc's Crops, Environment and Land Use Programmes to changes in the agri-food sector over time.

Teagasc's Crops, Environment and Land Use Programme (CELUP) strives to make an impact to the agri-food sector by bringing together several streams of work at different disciplinary, strategic and temporal scales. In November 2021, CELUP chose to highlight six case studies that did just that, as part of its peer review process.

The case studies are diverse, but one thing they have in common is that they began at least 14 years ago. Individually and collectively, they provide a fascinating insight into how CELUP research and knowledge transfer over time has contributed to the production of worthwhile outcomes for farmers, enterprises and policy makers. They also highlight how the ongoing and evolving relationships and interactions CELUP has with its networks have the potential to achieve greater impact on the sector in the future.

Each case study contributed to change along one or more of three identified pathways: technology development and adoption; capacity development; and policy influence. These pathways, outlined in Teagasc's Statement of Strategy 'Teagasc Together', depict an overarching model of how Teagasc contributes to developmental impact in the agri-food sector.

CASE STUDY 1

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Septoria control in winter wheat

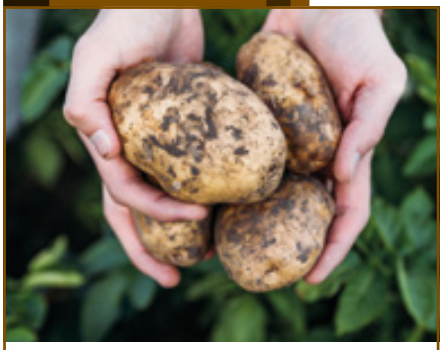
Pathway: Technology development and adoption

Teagasc researchers: Steven Kildea, Deirdre Doyle, Fiona Hutton and Ewen Mullin

This case study on managing septoria tritici blotch (STB) disease in winter wheat began in 2002, when STB was first recognised as a serious and persistent threat to Irish wheat production, and EU legislation towards fungicides was tightening. A subsequently developed network of Irish and UK public and private research and industry organisations implemented projects to tackle STB.

This case contributed to an increase in wheat yield from when STB was first identified as a problem, and winter wheat remains a successful economic crop in Ireland.

CASE STUDY 2



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Disease resistant potato varieties

Pathway: Technology development and adoption

Teagasc researchers: Dan Milbourne and Denis Griffin

This case study on breeding multi-disease resistant commercial potato varieties started in 2002, with the formation of a de facto potato breeding and genetics research group. Over time, a network sharing research results and promising sources of resistance and breeding lines was developed. This network included Teagasc, a potato Genome Sequencing Consortium of 15 research groups, Irish private industry and four European commercial breeding companies.

The main outcome was the release of *Buster* and *Java* multi-disease resistant varieties in 2019, which were bred in shortened time through the Marker Assisted Selection (MAS) tool. Long-term, MAS-driven breeding can contribute to crop protection applications and reducing the billions of euros in crop losses.

CASE STUDY 3

Changes in water quality and agricultural policy

Pathways: Capacity development; Policy influencing
Teagasc researchers: Owen Fenton, Karen Daly, Daire O'hUallachain, Per Erik Mellander, Eddie Burgess and Karl Richards

This case study on the changes in water quality and agricultural policy began in 1996, when the Environment Protection Agency (EPA) funded a research project led by Teagasc to quantify phosphorus loss from agriculture.

Over time, EU directives and regulations related to water quality as affected by agriculture in Ireland became informed and modified based on research findings, thanks to a network made up of government departments, state agencies, local authorities and funding bodies.

The case study showed successful input into the EPA River Basin Management Plan and a nutrient management policy, over three review cycles. It also led to an improvement in soil phosphorus management, thanks to the adoption of the case's online Nutrient Planning Management tool by over 60,000 farmers. Long-term, this case continues to contribute to reducing environmentally damaging nutrient runoff from agriculture.

CASE STUDY 4

Gaseous emissions policy and practice

Pathway: Policy influencing
Teagasc researchers: Gary Lanigan, Dominika Krol and Karl Richards

The initial work of this case study on gaseous emissions policy and practice in Ireland began in 2001, with the quantifying of nitrogen oxide and carbon sequestration. With the help of other research organisations and government departments, the 2012 greenhouse gas (GHG) Marginal Abatement Cost Curves (MACC) that came out of this study was instrumental in Ireland obtaining flexibility under the EU's 2030 Effort Sharing Regulation. Furthermore, the 2015 Ammonia MACC contributed to Ireland being set a smaller ammonia emissions cut from the EU.

The ongoing potential impact of this case is to make a significant contribution to Ireland becoming net zero by 2050.

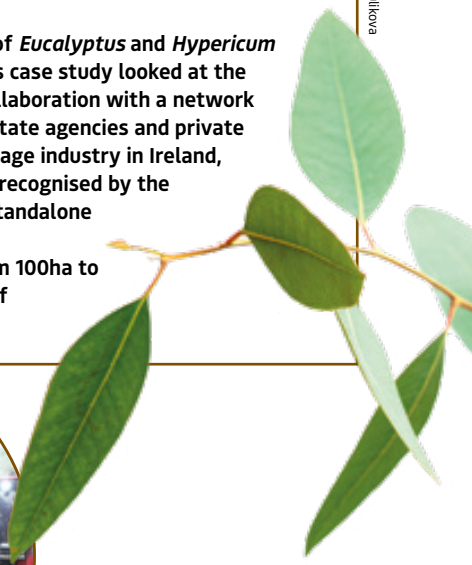
CASE STUDY 5

Development of the cut foliage industry

Pathway: Technology development and adoption; Capacity development; Policy influence
Teagasc researchers: Andy Whelton and Helen Grogan

Beginning in 1993 with the planting of three hectares of *Eucalyptus* and *Hypericum* and the recruitment of a foliage officer in Teagasc, this case study looked at the development of the cut foliage industry. A long-run collaboration with a network of research organisations, government departments, state agencies and private sector companies led to the establishment of a cut foliage industry in Ireland, which has an annual turnover of €7.5 million. It is now recognised by the Department of Agriculture, Food and the Marine as a standalone sub-sector of ornamental Irish horticulture.

The area planted to forest foliage has increased from 100ha to 200ha in the past five years, and by 2025, a turnover of €20 million is possible.



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CASE STUDY 6

Optimising conifer thinning

Pathway: Technology development and adoption; Capacity development; Policy influence
Teagasc researcher: Niall Farrelly
Forestry specialist: Tom Houlihan

This case study started in 2007, with research being carried out on the impact of thinning on financial returns to farm forest plantations. Over time, a network of forestry owner groups, forestry companies, forestry professionals and the Teagasc Forestry Development Department emerged, sharing a similar goal of co-creating a stronger timber supply chain, of which improved thinning of conifers is an important part.

The main outcomes achieved were improved capacity-building amongst forest owners and owner groups, building forest management skills and decision-making capacity, facilitating increased interaction with the industry and enabling sustainable timber mobilisation.

A successful forestry sector is crucial if Ireland is to reach its carbon reduction obligations. The fact that 14,000 owners out of 23,500 require ongoing support with thinning – which in turn increases income and provides a supply of raw material for processing – means there are very positive opportunities for the sector.

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On the scent: the aroma of raw milk

Pioneering research undertaken by Teagasc, in association with University College Cork, has shown how cows' diets affect the aroma of raw milk.

Ireland's predominantly pasture-based feeding system for milk production is relatively unique when compared to most other countries (which use a predominantly concentrate-based system). Many factors influence this decision, but it's mainly related to the fact that Ireland's climate makes it more economically feasible to do so.

It has long been believed that diet affects the flavour of raw milk, but this has proven difficult to verify without the identification of the specific compounds responsible. To address this, Teagasc and University College Cork (UCC) used a combination of techniques to successfully complete the first in-depth study demonstrating the impact of diet on the aroma of raw bovine milk.

Pasture vs non-pasture feeding

Previously conducted sensory studies have highlighted subtle differences in milk from pasture and non-pasture diets. Most of these differences relate to visual or textural differences, as these are easier to determine. Differences in colour relate mainly to a higher β-carotene (pigment) content in pasture-derived milk, giving it a more yellow or less white hue. Texture differences can be perceived in the mouth, due to changes in the fatty acid profile of milk.

Whilst flavour is a combination of taste and aroma, aroma has a much greater influence, so to improve their chances of success, the researchers focused on the volatile organic compounds (VOC) found within the raw milks.

Kieran Kilcawley, Teagasc Principal Research Officer and project member, says: "VOC are responsible for odour, so they're an important area of study.

"We also chose to focus on two main types of raw milk – milk produced from cows outdoors fed perennial ryegrass (GRS) in pasture-based systems, and milk produced from cows indoors fed a total mixed ration (TMR) diet – typically green fodder or silage blended with cereals, protein sources, vitamins and feed additives."

Did you know?

Pasture-based milk production systems are more positively perceived by consumers as they are typically considered more environmentally friendly, organic and better for animal welfare.

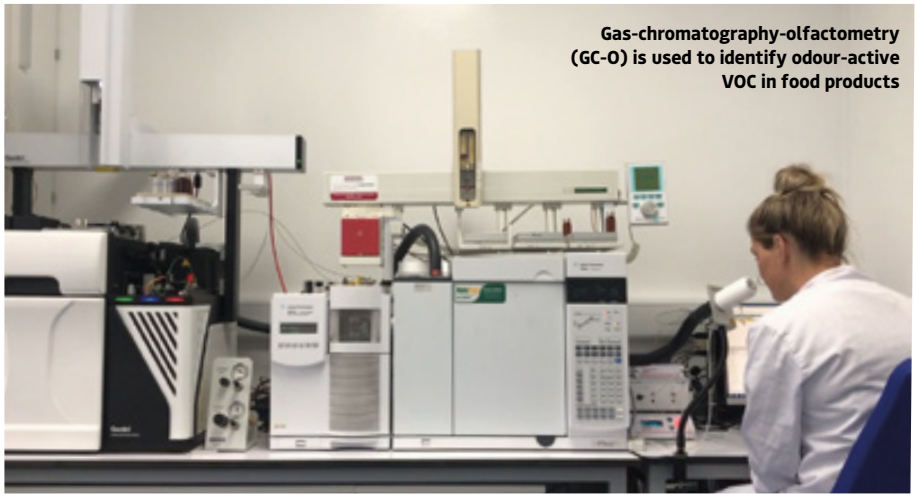
Identifying active aroma compounds

The VOC profile was extracted from the raw milk using a novel advanced high capacity extraction process. It was then separated and identified using an instrumental technique known as gas chromatography mass spectrometry.

"We identified 99 VOC in these milks – significantly more than any previous international study," says Kieran. "In addition, we demonstrated that 33 of these VOC were also present in the diet and in the rumen (stomach compartment), highlighting the significance of the direct transfer of VOC from feed to milk."

The results also highlighted that the VOC content of raw milk from pasture and non-pasture diets were very similar, which was in line with previous studies. Furthermore, the abundance of only 13 VOC varied significantly based on diet alone.

"This finding was very important as our ability to perceive aroma is impacted by both



Gas-chromatography-olfactometry (GC-O) is used to identify odour-active VOC in food products

In the past, it has been difficult to verify the long-held belief that diet affects the flavour of raw milk

~80% of flavour is influenced by aroma molecules.

Below are some of the aromas most associated with both perennial ryegrass and total mixed ration raw milk:

Roasted	Popcorn	Herbal
Toasted	Cheesy	Fruity
Potato	Sweet	Spicy

the abundance and the odour threshold (the concentration above which we can perceive it) of each individual VOC," explains Kieran.

"To determine which VOC influenced the aroma perception of these milks, we used a technique called gas-chromatography-olfactometry (GC-O). GC-O essentially involves trained panellists acting as an additional detection system in combination with the spectrometry detection.

"Using specific processes such as odour intensity (OI) and aroma extraction dilution analysis (AEDA), these panellists can describe individual odours from VOC, but also determine their relative intensity and therefore importance."

Very few GC-O studies have been undertaken on raw milk, potentially because of its subtle flavour, which makes it difficult to discern aroma characteristics. To overcome this, researchers ensured the VOC were concentrated sufficiently prior to separation by GC, in order for it to be more easily perceived by the olfactometry panellists. This was only achieved by using this novel high capacity sorptive extraction system.

Alternative influencing factors

Approximately 30% of the VOC were deemed odour-active by olfactometry. Even though the raw milks derived from both pasture and non-pasture diets shared many odour-active VOC, enough differences existed in their abundances to result in differences in their respective aromas.

Raw milk derived from a TMR diet was judged to have a higher OI, with many of the odour-active VOC derived from Maillard reactions (a non-enzymatic reaction indicated by heat). This led the researchers to conclude that they were directly transferred from the TMR, but must also have been created as a result of the heat-treatments used to produce the TMR feed itself.

"As the first of its kind, this study is important in our understanding of the relationship between diet and the aroma of raw milk," says Kieran. "It highlights the significance of both the direct and non-direct transfer of VOC from diet to milk, that subsequently influence aroma perception and thus flavour."

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Plasma: an alternative to chlorine disinfection

Teagasc researchers are exploring the use of novel plasma technology in the cleaning of food contact surfaces.

When microorganisms stick to food processing surfaces that haven't been properly sanitised, they can contaminate food products they come into contact with. They then form biofilms (one or more types of microorganisms that can grow on many different surfaces) that pose a major global challenge in the fight against product contamination.

As sources of contamination in food processing and drinking-water distribution systems, biofilms can be damaging to our health. The need to create effective techniques to counter biofilm infections presents one of the most pressing challenges in antibacterial research, as evidence indicates biofilm is becoming increasingly resistant to standard decontamination methods, such as chlorine and detergents, and antibiotics.

The World Health Organization has identified antimicrobial resistance as one of the greatest threats to human health. It has endorsed a global action plan for tackling this challenge, which includes encouraging research and development of new antimicrobial agents. To support this action, Teagasc has launched PASTE – a project exploring the use of novel technology, such as plasma, as an alternative to antimicrobial resistant disinfectants.

Chlorine disinfection in the food industry

Chlorine and chlorine-based disinfectants are the most commonly used chemical disinfectants in the food industry for microbial inactivation on food contact surfaces, due to chlorine's strong oxidising and disinfecting ability.

One issue with this method, however, is the entry of chlorine residues, such as chlorates, into the food supply chain. This occurs through the use of chlorinated water and through residual chlorine present in processing equipment. Clean-in-place procedures – used to automatically clean the inside of equipment such as pipes and filters – typically use chlorine-based sanitisers, both at processor and farm level, and are often responsible for this.

The presence of chlorates in food products has become a major food safety issue in the EU, as they are known to cause toxicological effects by inhibiting iodine uptake in humans – a mineral that helps our bodies to make thyroid hormones. A default maximum residual limit for chlorate of 0.01mg/kg is applicable for all foods, meaning a safer alternative is needed.

Factfile

Food-borne pathogens that cause food safety outbreaks such as *Salmonella, Escherichia coli and Listeria* can be found in fruit juices, fresh produce and meat products.

Plasma as an antimicrobial agent

Plasma – an ionised gas – has rapidly evolved as a technology for biological applications such as microbial decontamination, wound healing and cancer treatment. It has cytotoxic effects, which means it can damage cells or cause them to die.

> **The World Health Organization has identified antimicrobial resistance as one of the greatest threats to human health.**

The PASTE project team used plasma-activated water (PAW) – plasma treated with water – to conduct experiments, assessing its efficacy in disinfecting bacterial biofilms on food contact surfaces. The initial trials demonstrated the efficacy of PAW against key food spoilage microorganisms, reducing their presence by between 50% to 85% following a 15-minute treatment.

The project team is also investigating the effect of this PAW on chemical and structural changes on the biofilm matrix (mostly carbohydrates, proteins, lipids and extracellular DNA).

A promising technology

Given the unique species associated with such highly non-equilibrium plasmas, the approach suggests a breakthrough alternative to the use of chlorine for the cleaning of spray dryers, which would be effective against spore-forming bacteria and biofilms in food processing environments. It would also be environmentally friendly, quick to come into effect and result in no toxic residues.

The PAW will be used for the cleaning of the spray dryers in the dairy industry to check the efficacy of plasma to reduce the microbial load or contamination in the final products. Comparatively, after the application of chlorine for disinfection of the food contact surfaces, the dairy products will be checked for chlorate residues.

The possibility of novel technology such as plasma as a sanitiser for cleaning-in-place procedures on spray dryers and hot plate exchangers in the dairy industry can help to guarantee product safety and quality of dairy powder, which includes infant milk powder.

The PASTE project, therefore, is offering a revolutionary new approach and potentially 'green' solution to how we can reduce our dependence on synthetic chemicals and their associated environmental impacts. Such a change would not only benefit human health, but also contribute towards a more sustainable future for the agri-food industry. T

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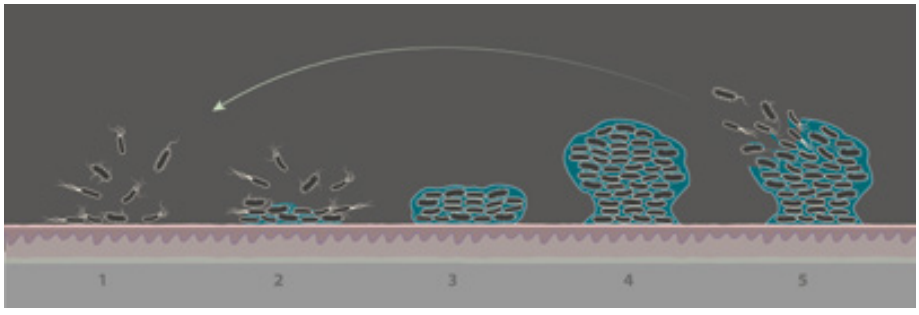

Figure 1. The biofilm formation process on abiotic and biotic surfaces

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Encouraging the entrepreneurial spirit

New Head of Technology Transfer and Commercialisation **Siobhán Jordan** anticipates the future of entrepreneurship and innovation at Teagasc.

Summertime always brings a sense of eager anticipation. It's a chance to enjoy better weather; meet up with family and friends; go on holiday; and catch up on reading.

And I feel that same sense of eager anticipation across all areas of Teagasc. Happily, this anticipation doesn't seem to be seasonal – it's been evident to me since I took up the role as Head of Technology Transfer and Commercialisation in mid-February 2022. Having spent over 20 years working at the interface of research and industry in Scotland, it has been exciting to return home to forge new connections in my role to support entrepreneurship and innovation.

Visits to Teagasc's many and varied research centres and unique facilities – including the National Prepared Consumer Food Centre (PCFC) and the National Innovation Hub – have highlighted the passion, enthusiasm and real interest in how world leading research in Teagasc can deliver innovation and solutions for national and international food and agri-tech companies.

Laying strong foundations for future success

Here in the Technology Transfer department, our work aims to build on the 'Teagasc Together' strategy of harnessing the power of research to create sustainable food systems.

For example, the newly launched Teagasc START fund for staff members is encouraging novel ideas that ultimately support a range of areas, including climate mitigation technologies, new or enhanced food and drink products and process innovations, or agricultural and agri-tech products, processes or services.

This fund is already making a huge impact – three projects funded during the pilot in 2021 have successfully completed their initial proof of concept, and are now progressing to the next stages of exploration.

Working with the team at VistaMilk SFI Research Centre, we're inspiring and nurturing impact from PhD students, post docs and early stage career researchers. Such support and guidance can be a game changer for those early on in their research journey.

It is encouraging that impacts are already being realised. In March 2022, Teagasc Research Officer Maria Hayes won the Teagasc Award at UCC's SPRINT Accelerator Programme – a programme designed to support early-stage start-ups and entrepreneurs. The programme has allowed Maria to explore potential pathways for PAW – a project focused on pet aging and heart health.

Teagasc and UCC's spinout company SeqBiome is also continuing to go from strength to strength, and is busy recruiting new staff members to support it in its high-quality and interactive microbiome sequencing and bioinformatics offer.

I have no doubt that as long as we continue to collaborate, network, translate research into technology offers and work with a visionary approach, we will unlock exemplar innovation and entrepreneurship. T

Maria Hayes (fourth from left) receiving the Teagasc Award at UCC's SPRINT event

2022

JUNE

Teagasc Sheep Open Day

Date 18 June

Location Teagasc, Animal and Grassland Research and Innovation Centre, Athenry, Co. Galway

This open day will offer an opportunity to review the latest research and technical advice from the Teagasc Sheep Programme and its practical application at farm level. There will be a mix of technical presentations and interactive workshops dealing with all the main areas important to Irish sheep production. The open day is free to attend and all sheep farmers and those involved in the sector are welcome.

- **Contact:** **philip.creighton@teagasc.ie**
- **More information:** **teagasc.ie/news--events/national-events/events/sheepopenday.php**

BovINE webinar: Increasing marbling in beef meat

Date 27 June

Location Online event

BovINE (Beef Innovation Network Europe) is an EU-funded thematic network focused on knowledge exchange to help address the challenges, and drive sustainability in, the European beef farming sector. To support its objectives, the network is hosting a webinar on increasing marbling in beef meat. .

- **Contact:** **maeve.henchion@teagasc.ie** or **richard.lynch@teagasc.ie**
- **More information:** **www.bovine-eu.net**

JULY

BovINE webinar: Animal welfare indicators and training on beef farms

Date 4 July

Location Online event

BovINE (Beef Innovation Network Europe) is an EU-funded thematic network focused on knowledge exchange to help address the challenges, and drive sustainability in, the European beef farming sector. To support its objectives, the network is hosting a webinar on animal welfare indicators and training on beef farms.

- **Contact:** **maeve.henchion@teagasc.ie** or **richard.lynch@teagasc.ie**
- **More information:** **www.bovine-eu.net**

Teagasc Beef Open Day

Date 5 July

Location Teagasc, Grange, Dunsany, Co. Meath

This open day will showcase the latest research from Teagasc Grange and the new knowledge transfer programmes: Future Beef Programme (for suckler systems) and Dairy Beef 500 (for dairy-beef systems). A major focus will be on the environmental sustainability of pasture-based beef cattle production, given the increasing focus from policy makers and consumers.

- **Contact:** **paul.crosson@teagasc.ie** or **pearse.kelly@teagasc.ie**
- **More information:** **teagasc.ie/news--events/national-events/events/beefopenday.php**

AUGUST

Johnstown Castle '22 Open Day: Technologies for farms of the future

Date 30 August

Location Teagasc, Environment Research Centre, Johnstown Castle, Co. Wexford.

What will farms of the future look like? This open day will demonstrate technologies and practices that can be adopted on farms to help maintain farm productivity and profitability, whilst increasing overall environmental sustainability. The latest information for successful management of grass-clover and multi-species swards under winter and spring calving dairy systems and dairy calf-to-beef systems will be available. Practices to enhance on-farm biodiversity and to reduce losses of valuable nutrients from the soil will be demonstrated. You will also learn about the latest fertiliser and slurry technologies and methods for enhancing carbon sequestration and soil health.

- **Contact:** **david.wall@teagasc.ie**

SEPTEMBER

5th Food Structure and Functionality Symposium

Date 18–21 September

Location Clayton Hotel Cork City, Cork, Ireland

Hosted by Teagasc and the Food Structure and Functionality Forum, this conference will bring together renowned speakers from academia and industry at the forefront of cutting-edge food science and technology. The theme for this year's conference is 'Structuring Foods for a Sustainable World'. Topics will include innovations in sustainable food processing, ingredient up-cycling and reducing food waste, alternative proteins and food structures for human health.

- **Contact:** **sean.hogan@teagasc.ie** or **andre.brodkorb@teagasc.ie**
- **More information:** **elsevier.com/events/conferences/food-structure-and-functionality-forum-symposium**

On Tenterhooks

Photographed here is a *Tipula oleracea* male – commonly known as a Daddy Longleg – holding onto some winter barley, using the hooks on the end of its legs.

The larvae of this cranefly can do severe damage to agricultural crops, as they feed actively on the roots. As such, it is important to correctly identify both adults and larvae to their species level, as different species have different lifecycles.

Photo and description by: Aisling Moffat, Teagasc Walsh Scholar
Teagasc project: Leatherjacket Biocontrol (in collaboration with Scotland's Rural College and the University of Edinburgh)