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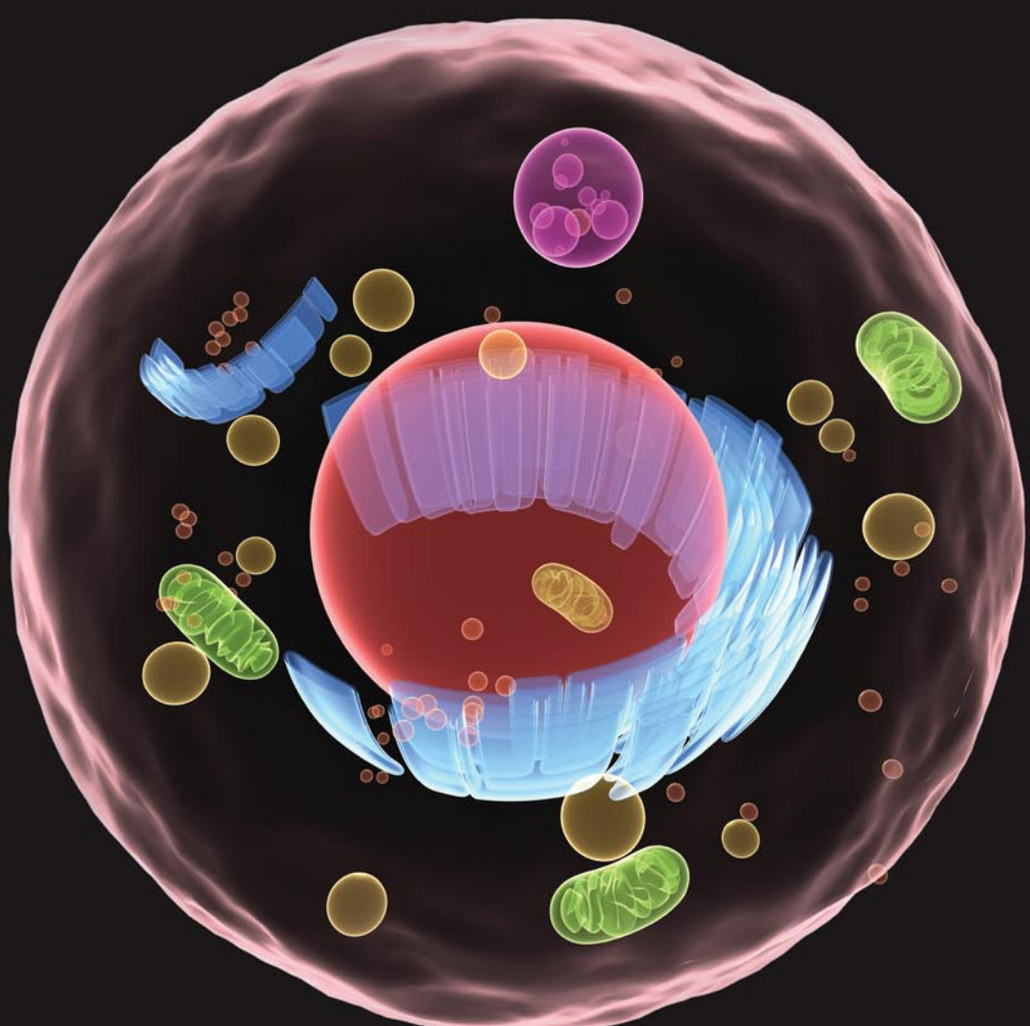
T Research

Research and innovation news at Teagasc



microRNAs - a quantum leap for biology

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TResearch
Teagasc | Oak Park | Carlow

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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T Editorial

Teagasc performs well in Forfás study

Forfás has published a bibliometric study of the public research base in Ireland as part of an exercise mapping research strengths here. Of all the public research organisations measured over the 10-year period from 1998 to 2007, Teagasc had the highest number of scientific papers published. The vast majority of the 1,367 Teagasc papers are in agriculture and food science, demonstrating Teagasc's core strength. The report noted a rising annual volume of papers in Teagasc (annual average of 175 for the period 2005-2007 versus 117 for the period 1998-2000).

The study assessed the quality of the publications using citation indices (number of times a paper is cited in other papers) normalised to the world average for the relevant year and subject to the Rebased Citation Index (RCI). The quality of Teagasc papers was consistently above the world average and on an increasing trend over time (e.g., RCI of 1.5 in 2007 versus a world average of 1.0). The report also noted that about one-third of Teagasc papers have a co-author from an Irish higher education institutions (HEI), and further notes that this is much higher than typically found in the UK between research institutes and HEIs. This reflects strong collaborative links between Teagasc and the third-level sector, which is undoubtedly driven in part by the Teagasc Walsh Fellowship scheme.

Scientific papers are the currency of research and it is heartening to see the strong performance of Teagasc in numbers and quality of publications. Peer-reviewed publications are an important assurance of the quality of the research undertaken and enhance the reputation of the individual researcher and of Teagasc. This study is an independent verification of Teagasc's performance and reflects the commitment of staff and management over many years to increase the number of papers published in peer-reviewed journals. The research reported in these papers is being used every day on our farms and in our food companies to help them compete in their global market.

The study can be accessed at http://www.forfas.ie/publication/search.jsp?ft=/publications/2010/title,7199,en.php.

Dr Frank O'Mara
Director of Research

Feidhmíonn Teagasc go maith de réir staidéar Forfás

D'fhoilsigh Forfás staidéar bibliméadrachta maidir leis an mbunachar taighde poiblí in Éirinn mar chuid de bheart chun an neart taighde a aimsiú anseo. I gcomparáid leis na heagraíochtaí taighde poiblí go léir le linn tréimhse 10 mbliana ó 1998 go 2007, is é Teagasc a bhfuil an líon is mó de pháipéir eolaíocha foilsithe aige. Tá 1,367 páipéar foilsithe ag Teagasc, agus baineann an formhór acu le talmhaíocht agus bia-eolaíocht, lena dtaispeántar an príomhneart atá ag Teagasc. Sa staidéar léirítear go bhfuil méadú ag teacht ar líon na bpáipéar arna bhfoilsiú ag Teagasc in aghaidh na bliana (meán bliantúil de 175 don tréimhse 2005-2007 I gcomparáid le 117 don tréimhse 1998-2000). Sa staidéar, rinneadh measúnú ar chaighdeán na bhfoilseachán, ag úsáid innéacsanna lua (an méid uaireanta a luaitear páipéar i bpáipéir eile) normalaithe ag an meán domhanda don bhliain atá i gceist, agus faoi réir an Innéacs Lua Athbhunaithe (RCI). Bhí caighdeán na bpáipéar Teagasc i gcónaí os cionn an mheáin dhomhanda agus á méadú de réir a chéile (m.sh., RCI de 1.5 in 2007 i gcoinne meán domhanda de 1.0) Aimsíodh freisin sa staidéar seo go bhfuil trian de na páipéir Teagasc le comhúdar ó Foras Náisiúnta Ardoideachas na hÉireann (HEI) agus chomh maith leis sin luaitear go bhfuil sé seo i bhfad níos airde ná na naisc idir forais taighde agus HElanna sa Ríocht Aontaithe. Leis seo, léirítear naisc chomhoibrithe láidre idir Teagasc agus an earnáil tríú leibhéil, atá tiomanta gan amhras ag an scéim Comhaltachta Teagasc Walsh.

Tá páipéir eolaíoch mar airgeadra sa réimse taighde agus tá sé dóchasach an feidhmiúchán láidir atá ag Teagasc a fheiceáil i líon agus caighdeáin na bhfoilseachán. Is deimhniú tábhachtach iad foilseacháin arna n-athbhreithniú ag piaraí den cháilíocht agus taighde a dhéantar agus feabhsaítear cáil an taighdeora aonair agus cáil Teagasc chomh maith. Is fíorú neamhspleách é an staidéar seo d'fheidhmiúchán Teagasc agus léirítear tiomantas na foirne agus bainistíochta le linn na mblianta d'fhonn líon na bpáipéar arna bhfoilsiú in irisí athbhreithnithe ag piaraí. Tá an taighde a thuairiscítear sna páipéir seo á úsáid gach lá ar ár bhfeirmeacha agus inár gcuideachtaí bia chun cabhrú leo dul san iomaíochas sa mhargadh domhanda. Is féidir teacht ar an staidéar ar http://www.forfas.ie/publication/search.jsp?ft=/publications/2010/title,7199,en.php.

An Dochtúir Frank O'Mara
Stiúrthóir Taighe

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T News

Researcher profile

Dr Peadar Lawlor

Dr Peadar Lawlor is a Principal Research Officer at the Teagasc, Pig Production Development Department, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co Cork. His research interests include: investigation of novel pig feed additives; heat processing of feed ingredients and animal feeds; post-market monitoring of genetically modified animal feed ingredients; nutritional and post-slaughter factors affecting meat eating quality; pre-natal muscle development; *Salmonella* control; and, energy from pig manure.

Peadar graduated from University College Dublin in 1991 with a BAgrSc in Animal & Crop Production, received his MAgrSc from the university in 1993, and his PhD in Agricultural Science (Pig Nutrition) in 2001. During this time he also worked as a Pig Enterprise Adviser based in Bagenalstown (until 1997), and as a Research Officer in the Pig Husbandry Department, Moorepark (until 2002). From 2002 until 2004 he taught at Clonakilty Agricultural College, teaching FETAC and HETAC-accredited agricultural courses.

Peadar joined the Pig Development Unit in 2004. He has been project leader on a number of projects, including 'Identification of novel and previously suspected gene targets whose expression in offspring may be affected by gestation feeding regimes in pigs'. He was a member of the Management Committee for the EU COST Action 925 'The importance of prenatal events for postnatal muscle growth in relation to the quality of muscle-based foods'. He is a member of the Peer Review College of the Danish Council for Strategic Research and a past member of the European Food Safety Authority scientific panel on additives and products/substances used in animal feed (FEEDAP). He provides back-up and in-service training to the Teagasc pig advisory team and is involved in the development and delivery of training courses and workshops for staff of pig units, the meat industry, the feed industry and financial institutions.

Peadar has presented numerous scientific papers at international meetings. Most recently his contributions to peer-reviewed publications include co-authorship of: '*Prebiotics from marine macroalgae for human and animal health applications' in Marine Drugs (2010);* and, 'Developmental programming of skeletal muscle phenotype/metabolism' in *Animal* (2009).

On a more personal note, his interests include the GAA, travelling, golf, shooting and reading.

Teagasc Director elected to RIA

Teagasc Director Professor Gerry Boyle has been elected a member of the Royal Irish Academy (RIA). The RIA is an all-Ireland, independent academic body that promotes study and excellence in the sciences, humanities and social sciences. It is the principal learned society in Ireland and has over 420 members who are elected in recognition of their academic achievements.

Managing grain price volatility

Selling grain over the last few years has become a lot more difficult, with massive fluctuations in price over a selling period. At the Teagasc National Tillage Conference in Carlow, grain growers heard how volatile world grain markets are forcing more farmers to use risk management strategies to minimise the impact of price fluctuations on their businesses. John Spink, Head of Crop Science Department, Teagasc, said: "Irish farmers have tended to sell most grain 'green' off the combine, which has left them vulnerable to price volatility.

This year is the first year where the opportunity to sell grain in advance of harvest has been more widely available to all growers".

The largest costs on cereal farms are machinery costs, and Teagasc researcher Dermot Forristal said that National Farm Survey data indicates that machinery costs on tillage farms are high, at €357 per hectare, representing 44% of production costs. He pointed out that similar survey data from the UK indicates lower machinery costs on UK farms.

Research carried out as part of the crops research programme in Oak Park indicates a high range of machinery costs on farms, highlighting the scope for cost savings and the importance of getting the mechanisation strategy right for individual farms.

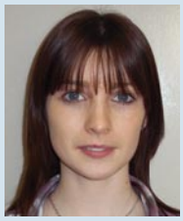
Certified cereal seed key to successful crops

Genetic improvement and the consequent productivity benefits are key to enhancing the competitiveness of the Irish farming industry, according to Professor Jimmy Burke of Teagasc, Oak Park.

Speaking at the launch of a new information booklet on certified seed, he said: "Plant breeding techniques are continuously evolving. We must continue to facilitate the development and commercial introduction of better plant genetics into Irish farming systems, thus improving and safeguarding our national competitiveness in a fast evolving globalised market".

Donal Fitzgerald, President of the Irish Seed Trade Association, said: "Plant breeding and the commercial introduction of a new variety is an expensive and time-consuming operation and on average takes 10 years before a new variety is ready for the market. This process has to be continually funded to ensure viability, and if not, then the introduction of newer and better varieties ceases to be a reality". Visit http://www.agriculture.gov.ie/farmingsectors/ crops/seedcertification for more details on seed certification.

Teagasc researchers successful in EAAP funding applications



Three Teagasc researchers have submitted successful funding applications for travel bursaries to the Department of Agriculture, Fisheries and Food. Sarah Keady, a PhD Walsh Fellow supervised by Dr Sinead Waters; Aran O'Loughlin, a PhD Walsh Fellow supervised by Dr Bernadette Earley; and, Dr Keelin O'Driscoll, a Marie-Curie experienced scientist carrying out postdoctoral research with Dr Bernadette Earley, submitted abstracts to the Department, and each has been awarded a €1,000 bursary.

Designer probiotics could reduce obesity

Specially designed probiotics can modulate the physiology of host fat cells, say a team of Teagasc and UCC scientists writing in *Microbiology*. The findings could lead to specialised probiotics that have a role in the prevention or treatment of conditions such as obesity. Scientists from the Alimentary Pharmabiotic Centre (APC), University College Cork, and Teagasc engineered a strain of *Lactobacillus* to produce a version of a molecule called conjugated linoleic acid (CLA).

When this engineered bacterial strain was fed to mice, the researchers found that the composition of the mice's fat tissue was significantly altered, demonstrating that ingesting live bacteria can influence metabolism at remote sites in the body. Dr Catherine Stanton from Teagasc, who led the study, explained the significance of the results. "CLA has already been shown to alleviate non-alcoholic fatty liver disease that often accompanies obesity. Therefore, increasing levels of CLA in the liver by ingestion of a probiotic strain is of therapeutic relevance," she said.

Appointments

Dr Juan Valverde has been appointed to the Editorial Board of the *Journal of Culinary Science and Technology*.

Dr Geraldine Duffy, Head, Food Safety Department, Teagasc Food Research Centre, Ashtown, has been appointed to the Scientific Committee of the FSAI.

Congratulations to both on these prestigious appointments.

Teagasc Nutraceutical Research Facility opens in Dublin

Commissioner Maura Geoghegan-Quinn receives a tour of the Teagasc Nutraceutical Research Facility, Ashtown, Dublin.

To launch a high-tech, state-of-the-art research facility at this time demonstrates faith in the future of the Irish agri-food sector and in Ireland's talents in research and science as a springboard to growth and jobs. Those were the words of EU Commissioner Maire Geoghegan-Quinn at the opening of the Teagasc Nutraceutical Research Facility at Ashtown in Dublin. Commissioner Geoghegan-Quinn said: "The agri-food industry was at the cutting edge of innovation before the word 'innovation' became part of the language of economic recovery.

I am confident that this facility will make a substantial contribution to efforts to improve human health, the quality of life of our European citizens and the competitiveness of the European food industry". Director of Teagasc Professor Gerry Boyle said: "Teagasc has built the capacity for food innovation on a foundation of research excellence.

The Teagasc Food Programme has pursued a particular policy of innovation and technology transfer with the aim of bridging the gap between public research and industry," he said.

Teagasc will be represented on Beef 2020 activation group

The then Minister for Agriculture and Food, Mr Brendan Smith, announced the establishment of an action-focused group to implement the recommendations of the *Food Harvest 2020* report in relation to beef.

The group will be chaired by Mr Michael Dowling, former Secretary General of the Department of Agriculture, Fisheries and Food, and will involve processors, farmers, Teagasc and the Irish Cattle Breeding Federation (ICBF).

T News

Obituary – Paddy Geoghegan

The death occurred last September of Paddy Geoghegan.
Although never a household name in the Irish farming world, Paddy played a vital role in the development of agriculture in this country in the '60s, '70s and '80s. Paddy was pivotal in making sure that the research carried out in An Foras Taluntais (AFT) was up to standard in every way.
As editor of *The Irish Journal of Agricultural Research*, he submitted each paper to a rigorous vetting process. He was a man of high principles, high standards and complete professionalism, who made it impossible for any researcher to get less than excellent work published. On a personal level, Paddy coped with difficulties for over 50 years that few could have endured. At the start of his career in 1955, as an agricultural graduate working with the Sugar Company in Cork, he contracted polio, which paralysed him from the waist down and confined him to a wheelchair. In spite of this, he lived a full working and social life, had a completely positive outlook and never complained.
Unknown to many people, Paddy Geoghegan made a massive contribution to Irish agriculture and he will be sorely missed by his relations, colleagues and friends.
Brian Gilsenan

Smith announces new agri-research advisory group

The then Minister for Agriculture, Fisheries and Food, Brendan Smith, recently confirmed the implementation of another key recommendation of the *Food Harvest 2020* Strategy – the establishment of the Agri-Research Expert Advisory (AREA) Group – which will be responsible for developing a strategic research agenda for agriculture research. Minister Smith said: "Continued investment in research and development will be of crucial importance to enable the growth targets for the sector as set out in *Food Harvest 2020* to be achieved. I am delighted to announce details of this new group and I am confident that with the assistance of all of the stakeholders, this group can make a significant contribution to the development of a research agenda for agricultural production public good research". Dr Frank O'Mara, Director of Research, Teagasc, has been appointed to the group.

Teagasc research opens genomic selection to farmers

New research carried out by Teagasc in collaboration with industry has reduced the cost of genomic testing by approximately one-third. This will allow Irish dairy farmers to genomically test their breeding animals, facilitating more informed breeding decisions and increasing the genetic merit of their herds.
In 2009 genomic selection was launched in Ireland, following research carried out by Teagasc, led by Dr Donagh Berry in collaboration with the Irish Cattle Breeding Federation (ICBF). Up to now the cost of the technology has been prohibitively expensive for individual dairy farmers. Now, the research team has developed a new method, which uses a lower cost technology with minimal compromise in accuracy. The results of this research are now available to farmers through a new service launched by the ICBF. Teagasc Director of Research Dr Frank O'Mara said: "This is a great example of science in action, delivering new technologies that will benefit Ireland and Irish dairy farmers". Head of Programme Dr Pat Dillon said: "This new genomic service can speed up the rate of genetic improvement of our national herd, and help our dairy industry improve its competitive position internationally". This research was funded from a range of sources including the Dairy Levy, the Stimulus Research Fund, FP7, Teagasc, the ICBF and the AI industry, and carried out by Teagasc at the Animal & Grassland Research and Innovation Centre, Moorepark, in collaboration with other Teagasc centres.

Ireland best in EU for carbon footprint of milk, pork and poultry meat

Image courtesy of Bord Bia.

The carbon footprint of Irish food products has been rated as among the best in the EU according to a major study just published by the Joint Research Centre of the EU Commission. The study, entitled 'Evaluation of the livestock sector contribution to the EU greenhouse gas (GHG) emissions', evaluated the full net carbon emissions of a range of livestock products, taking account of all on-farm emissions related to livestock rearing and the production of animal feed (even where this feed production takes place outside the EU), as well as emissions caused by providing input of mineral fertilisers, pesticides, energy and land for the production of feed. This cradle-to-gate life cycle analysis gives a comprehensive assessment of different production systems. Irish milk, pork and chicken were found to have the lowest carbon footprints in the EU, while the carbon footprint of Irish beef is the 5th lowest. Welcoming the publication of the study, Teagasc Director of Research Dr Frank O'Mara, who was a member of the project advisory board, said: "This study is particularly important as it is the first time such a range of products has been compared across all EU countries in a single comprehensive study. This will help to shape future policy and strategy in relation to the twin goals of food security and climate change". The report can be downloaded at: http://ec.europa.eu/agriculture/analysis/external/livestock-gas/index_en.htm.

T Science Week 2010

Anthelmintic residues in milk

MICHELLE WHELAN won the RDS gold medal for best presentation and the IFSTI president's medal for best food science and technology presentation at the annual Teagasc Walsh Fellowships seminar in the RDS for her presentation on 'Determination of anthelmintic residues in milk using UPLC-MS/MS with rapid polarity switching'. Michelle explains the significance of the research to the Irish dairy industry.

Chairman, RDS Committee of Agriculture & Rural Affairs, Jim Flanagan, with Michelle Whelan, Ashtown Food Research Centre, Walsh Fellow of the Year and winner of the RDS medal, and Teagasc Director Professor Gerry Boyle.

Anthelmintic drugs are widely used to control roundworm, tapeworm, liver-fluke and stomach-fluke infections in food-producing animals. However, only a limited number of drugs are licensed for use in lactating animals and have a maximum residue limit (MRL) listed under European Council Regulation 470/2009/EC. There is concern that the limited number of licensed products, and the development of drug resistance, could increase the potential for off-label applications in animals. A number of these substances have undesirable toxic effects at high doses in laboratory animals, but levels detected in food are generally well below toxicity thresholds. However, integrated parasite control programmes are an important part of modern agriculture and are necessary to maintain animal health and production yields.

A new rapid analytical method was developed to test for 38 anthelmintic drug residues in milk in a 13-minute run. It is the only test method available for the simultaneous detection of both worm and fluke products. The benefit of this new extraction method is that it is very quick, with few steps, and allows 36 samples to be tested daily. This new method is also extremely sensitive and can detect residues to trace levels. In addition, the amount of solvent used is greatly reduced and very little waste is generated due to the quick extraction and rapid analytical method.

The method, developed at Teagasc Food Research Centre, Ashtown, was transferred to the National Reference Laboratory (NRL) for anthelmintic drugs in late 2008 and was accredited by the Irish National Accreditation Board (INAB) to ISO 17025. It has been applied to milk samples collected as part of official food inspection. This resulted in the detection of low levels of flukicide residues in milk, which led to several veterinary products being restricted in dairy animals by regulatory agencies (Irish Medicines Board [IMB]). In subsequent research, the method was used to investigate the persistence of flukicides in the milk of dairy cows treated during lactation with the following drugs: nitroxynil, oxyclozanide, clorsulon and triclabendazole. These studies generated new knowledge, which can be used by risk assessors, decision makers and animal health companies to set suitable withdrawal times for veterinary medicines to ensure the safety of milk. The results from this research on the persistence of drugs in dairy animals can also support the development of new veterinary medicinal products for the treatment of infections in dairy cows. This will lead to improved labels on veterinary medicines, which inform farmers to adopt best practice.

This new sensitive test method used to monitor the purity of milk has improved the safety of Irish milk, and supports the export of Irish produce. This research will underpin the green image of Irish dairy products to ensure consumer confidence and safeguard international investment in the sector. One of the major outcomes of this work was the setting of provisional MRLs by the European Medicines Agency (EMA) for triclabendazole and closantel in milk following requests by the IMB under Article 9 of EC regulation 470/2009/EC. This is the first time a government agency has proactively sought for an MRL to be established. This is one of the most important developments from this work.

This research was funded by the Department of Agriculture, Fisheries and Food under the Food Institutional Research Measure as part of the National Development Plan and by the EU Framework 6 Programme on Food Quality and Safety, ProSafeBeef.

Michelle Whelan is a Teagasc Walsh Fellow at Teagasc Food Research Centre, Ashtown, and Cork Institute of Technology (CIT). Her supervisors are **Dr Martin Danaher** (Teagasc) and **Dr Ambrose Furey** (CIT).

T Science Week 2010

Teagasc Science Week events

Teagasc runs a series of events during Science Week each year.

Megan King from Clifden at the Teagasc Animal & Grassland Research and Innovation Centre in Athenry, Co. Galway.

Sinead Phelan of Teagasc, Crops, Environment and Land Use Research Centre, Oak Park, Carlow, explains plant biotechnology to Oluwaseun Ogunbiyi and Jonathan Gaboulaud from Carlow Institute of Technology.

Students from Castleknock College, Dublin, learned how to make sausages at Teagasc Ashtown Food Research Centre.

The aim of Science Week is to "promote the relevance of science, engineering and technology in our everyday lives and to demonstrate the importance of these disciplines to the future development of Irish society and to the economy". Teagasc supports the Forfás Discover Science and Engineering initiative by holding a series of events nationwide, with attendance by about 850 students. New this year, a competition for secondary school students was held on Twitter – http://twitter.com/cbteagasc. Also, a feature by Teagasc Remote Sensing Specialist Dr Stuart Green on 'Farming from Space – How Teagasc Uses Satellites and Aircraft to Research Agriculture in Ireland' appeared on the Science Week website – http://www.scienceweek.ie/features_2010_farming_from_space.asp.

Walsh Fellowships seminar

The theme of Science Week 2010's Walsh Fellowships seminar was: 'The Walsh Fellowship Scheme's contribution to delivering the vision for the agri-food sector outlined in the *Food Harvest 2020* report'. Opening the seminar, Teagasc Director Professor Gerry Boyle said: "This vision is based on two key actions – acting smart and thinking green to achieve the ambitious growth targets for the agri-food sector. The importance of innovation, to use new and existing knowledge, to drive profitability and sustainability in the sector, is now more important than ever. Success in this new and very competitive environment depends on primary producers and processors being smarter and greener in terms of the range of products and services required by increasingly aware consumers". The 2010 winner of the RDS medal was Michelle Whelan, a Walsh Fellow at Teagasc Food Research Centre, Ashtown, who presented a paper on 'Determination of anthelmintic residues in milk using UPLC-MS/MS with rapid polarity switching' (see article on p.7). The winner of the best poster was Burkart Dieterich, a Walsh Fellow at Teagasc Crops, Environment and Land Use Research and Innovation Centre at Oak Park, Carlow, for his poster on 'Fertiliser value and environmental impact of digestate application on permanent grassland' (see article on p.18). This year for the first time a President's medal donated by The Institute of Food Science and Technology Ireland (IFSTI) was presented to the best food science and technology presentation. This was also won by Michelle Whelan. Gráinne Kavanagh received an award for second place in this category for her presentation entitled: 'Technological innovation: investing in the future sustainability of the Irish food industry'. Both researchers received one year's free membership to the IFSTI from its President, Rory Ryan.

Keynote speaker Professor Gerald Fitzgerald

Professor Gerald Fitzgerald, Professor of Food Microbiology, UCC, delivered the keynote address to the seminar. He stressed the importance of people and the development of human capital as key drivers in developing the innovative smart economy. He said: "The smart economy applies as much to the agri-food sector as to other high value sectors in Ireland, perhaps even more so because it is such a large indigenous industry, contributing €24 billion to the economy annually. Teagasc Walsh Fellows are operating at the very cutting edge of knowledge. If we are seen as being the best we can act as a magnet to attract inward investment to Ireland". Professor Fitzgerald highlighted the significant contribution the Walsh Fellowships Programme has made to generating real

Ian O'Loughlin, Teagasc Food Research Centre, Moorepark, with pupils from Coláiste an Chraoibhín, Fermoy.

Dr Veronica Nyhan and students from St Kieran's College, Kilkenny, examining the digestive system of a ruminant animal at Kildalton College.

Dr Orla Keane, Molecular Biologist, Teagasc Animal & Grassland Research and Innovation Centre, Grange, with Eureka 6th year students from Kells, Co Meath.

Dr Daire Ó hUallacháin speaks to transition year students from CBS Wexford, about biodiversity at Teagasc Johnstown Castle Environment Research Centre, Wexford.

Keynote speaker, Professor Gerald Fitzgerald, Professor of Food Microbiology, UCC, at the Teagasc Walsh Fellowships Seminar.

links to the food industry, highlighting that cheese and probiotic products generated from research performed by Walsh Fellows are now on the marketplace. He acknowledged that the third-level sector is a major beneficiary of the Walsh Fellowship programme and said that the programme has had a formative role in the new UCC/Teagasc Strategic Alliance, launched last April.

Acknowledgments

Well done to the Teagasc Science Week Committee and all those involved, who ensured the successful running of events. For more on Science Week see: www.scienceweek.ie.

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T Feature

Grasses for the future

DR MICHAEL D. CASLER, United States Department of Agriculture's Agriculture Research Service, summarises the main points from the international conference 'Perennial ryegrasses: current and future genetic potential', which took place last October.

The 'Grasses for the Future' conference drew an audience of nearly 300 people over two days, representing the elite of Irish forage and livestock producers, many members of the grass seed industry, numerous grass breeders representing both public and private programmes, and grassland and livestock researchers from several locations in Ireland. Nine speakers presented papers on a range of topics related to future needs for grass production in Ireland, generating considerable discussion following each paper and during the second day of the conference. This report contains a brief summary of the most important points of each paper, followed by conclusions from the breakout discussion sessions of the second day.

Summaries

DR MICHAEL O'DONOVAN, Animal & Grassland Research and Innovation Centre, Teagasc, Moorepark, demonstrated the huge value of grass-based grazing systems to Irish farmers, particularly in the face of lower commodity prices, proposed removal of subsidies and tariffs, and rising input costs. Approximately 130,000 Irish farmers are involved in ruminant production, with a farm-gate value of €4.7 billion in 2009. Research has demonstrated that grass utilisation by grazing represents the most profitable and sustainable system of livestock production in Ireland. "To maintain a competitive edge, improved winter/spring growth, increased nutritional value, more favourable sward structure for grazing, and persistence under farm conditions should become traits of greater emphasis in breeding programmes," explained Dr O'Donovan. "There is also a need for improved synchronisation and communication between grassland farmers and researchers, evaluators and breeders."

DR PETER WILKINS, IBERS, Aberystwyth, showed that annual yield and persistence of perennial ryegrass in Europe has increased by about 20-25% during the past 40 years because of selection and breeding. "Considerably greater gains have been made in more recent years with the employment of intensive recurrent selection schemes adapted from maize breeding, largely by selection within fairly narrow populations. It is clear that there is considerable potential to continue making genetic improvements to perennial ryegrass, not only for annual yield, but for other traits as well," said Dr Wilkins.

DR ALAN STEWART, PGG Wrightson Seeds, New Zealand, provided an international perspective on perennial ryegrass breeding, illustrating that only 2,000 hectares of seed production are required to meet Ireland's annual seed needs. "Future investments in breeding are highly dependent on the economic success of seed companies and are not likely to increase. Ryegrass breeding is complicated by the need for multiple-trait selection, taking into account numerous traits that fall into the broad categories of yield, quality and persistence, each of which may interfere with gains to be made for other traits," explained Dr Stewart.

Pictured at the Teagasc 'Grasses For The Future' Conference were (back row from left): Declan McCarthy, Moregrass; Lex van de Weerd, Barenbrug; John Murphy, Goldcrop; Trevor Gilliland, AFBI; Pearse Kelly, Teagasc; and, Pat Dillon, Head, Teagasc Animal & Grassland Research and Innovation Centre, Moorepark. Front row: Oliver Vaughan, Germinal Seeds; Eva Lewis, Teagasc, Moorepark; Professor Gerry Boyle, Teagasc Director; Deirdre Hennessy, Teagasc, Morepark; and, Michael O' Donovan, Teagasc, Moorepark.

DR PATRICK CONAGHAN, Crops, Environment and Land Use Research Centre, Teagasc, Oak Park, Carlow, reported on the potential of utilising biotechnology in a practical breeding programme, demonstrating how DNA markers may provide very large increases in the rate of progress made by grass breeders. "Cost of technology development is the greatest impediment to utilisation of marker-selection technologies, but dairy cattle models can be utilised to develop shared marker resources, while maintaining marker-trait associations as proprietary technologies owned separately for each partner," he said.

DERMOT GROGAN, Crops Evaluation and Certification Division, Department of Agriculture, Fisheries and Food, Backweston Farm, Co Kildare, presented results of grass evaluation programmes in both the Republic of Ireland and Northern Ireland. Reducing the number of test sites used for decision-making increased the "breeder's risk" of having an improved variety incorrectly rejected. "Due to genotype–environment interactions, a minimum number of locations and years is necessary to maintain the integrity of the evaluation system. Both National Lists and Recommended Lists are highly influential, as nearly all varieties sold were recommended in one or both jurisdictions. Current initiatives are focused on development of a variety index that will incorporate multiple traits and trait weights to more efficiently rank varieties for suitability to a specific livestock management system."

DR MARY McEVOY, Animal & Grassland Research and Innovation Centre, Teagasc, Moorepark, reported on the initial development of the Economic Selection Index for grass varieties, using the Moorepark Dairy Systems Model as the basis for assigning

economic weights to individual traits. "The model was highly robust with respect to changes in production scenario, resulting in no changes to variety rankings. The feasibility of an Economic Selection Index to more efficiently and effectively rank varieties for their suitability to specific livestock production systems was effectively demonstrated," said Dr McEvoy.

DR LAURENCE SHALLOO, Animal & Grassland Research and Innovation Centre, Teagasc, Moorepark, showed that the annual reseeding rate for perennial ryegrass in Ireland is only about 2% of the land on commercial dairy farms. "Economic simulation models showed that an additional €923 could be earned on a 40 hectare dairy farm by each additional 1% increase in annual seeding rate. Reseeding is expected to have a significant and positive effect on profitability, due to increases in production per hectare and to the ability to increase stocking rate and herbage utilisation," he said.

DR TREVOR GILLILAND, Agri-Food Biosciences Institute, Crossnacreevy, Co Down, Northern Ireland, reported research results on perennial ryegrass seed mixtures, demonstrating that mixture yields did not differ from their theoretical yields, based on the components. "The advantage of mixtures derives from their increased yield stability, expressed as flatter seasonal yield production profiles. Mixtures with the widest range in heading date among the variety components had the greatest yield stability across years, but were also associated with declining yield advantage over time compared to the weighted average of their components. Tetraploids were generally more competitive than diploids, particularly so for the diploids with a dense sward growth habit. Manipulation of component ratios can be used to influence the sward composition over time," Dr Gilliland concluded.

DAVID LONG, Barenbrug UK Ltd, reported on the process and logistics of variety development with a private sector perspective. "The average cost of variety development is €600,000 and requires 16 years from initial cross to initial seed sales. Much less than 1% of materials developed by the breeder will ever reach the marketplace. Most of the costs in breeding varieties derive from extensive regional testing of large numbers of early-generation materials, entry into obligatory national and recommended list trials, several generations of seed multiplication, and marketing investments. A successful grass breeding programme involves expertise in the development of market-aware breeding goals, implementation of those goals in a field-based screening and evaluation programme, and delivery of certified seed to farmers," said Dr Long.

Conclusions

Breeding goals

The seeds sown at this conference will require time before their benefits are realised. Grass breeders can respond fairly rapidly to changes in breeding goals, but the length of time required for official trials and seed multiplication are generally fixed. Changes in breeding goals are not trivial and should take careful account of Ireland's future, particularly as influenced by:

1. Government policies and quotas.
2. Anticipated climate change.
3. Predicted changes in livestock genetics and management.
4. Needs for improved nutrient and energy efficiencies.
5. Producer and consumer preferences and pressures.

Room for improvement

Grass-based grazing systems are currently the most profitable form of livestock production in Ireland, but there is considerable room for improvement in profitability and sustainability. New grass varieties should be developed to allow farmers to respond to any and all of the above factors of change. Emphasis should be placed on traits that allow:

1. Reduction of input costs.
2. Maximum possible grazing days on pasture.
3. Maximum flexibility across a range of environmental conditions and management systems.

Considerable consensus was achieved that breeding programmes should begin to place some emphasis on some new breeding objectives, including:

1. Increased winter/spring productivity to support calving and lactation.
2. Increased summer quality to support reproduction.
3. Increased extent and stability of persistence to support a more sustainable production system.

Considerable concern was expressed about the known trade-offs between increased winter production and decreased winter hardiness, providing some caution to breeders and evaluators to design imaginative and fundamentally sound screening procedures to preserve the value and ensure the success of new varieties. Biotechnology could play a significant role in this process, provided development funds are available, increasing the rate of gain per year, but not necessarily producing new varieties more rapidly.

Economic Selection Index

Development of an Economic Selection Index appears to be a significant step towards linking breeding objectives, evaluation programmes and farmers' needs. There was strong support during the conference to strengthen these linkages through enhanced lines of communication, education programmes, and increased use of livestock in the breeding and evaluation processes. The index provides a mechanism to enhance these linkages, by quantifying the economic value of traits and providing a direct measure of the economic value of a variety in a specific grass and livestock management system. Both breeding and evaluation programmes may be required to expand their objectives in order to meet the needs of multiple environmental considerations and management systems, e.g., grazing *vs.* silage-based systems or different climatic zones. In plant breeding and variety evaluation, "you get what you select". There was clear consensus that some modification of both breeding and evaluation programmes will be necessary to respond to farmers' needs as outlined above. There was a general consensus that development of new varieties with desirable traits would lead to increased reseeding rates. There was also some desire, among the top forage and livestock producers, for an opportunity to try monocultures of a single top variety on their farms.

This conference was organised by the Teagasc Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co Cork, in conjunction with the Department of Agriculture, Fisheries and Food. The peer-reviewed proceedings will be published in a special edition of the Irish Journal of Agricultural and Food Research.

Dr Michael D. Casler is a Research Geneticist, United States Department of Agriculture – Agriculture Research Service, US Dairy Forage Research Center, Madison, Wisconsin, USA. For further information on the conference, contact Dr Michael O'Donovan. E-mail: michael.odonovan@teagasc.ie.

Science delivers results for farming and environment in nitrates review

The Teagasc Water Framework Directive Working Group submission to the Department of Environment, Heritage and Local Government has resulted in changes to the legislation that have benefits for both farmers and the environment.

Image courtesy of Bord Bia.

Implementation of the nitrate regulations is expected to reduce point-source losses and incidental losses from agriculture to water, and to lead to a decline of diffuse losses over time.

In 2008, the Teagasc Water Framework Directive (WFD) Working Group was set up to address numerous calls for stakeholder comment on issues relating to water and agriculture. In September 2009, the group commenced a comprehensive review of the scientific and administrative aspects of the Good Agricultural Practice for Protection of Water Regulations (nitrates regulations). This review resulted in a detailed submission being made to the Department of Environment, Heritage and Local Government as part of the consultative process to review the nitrates regulations (Schulte *et al.*, 2010). In its submission, Teagasc outlined a suite of proposed amendments to the regulations, which were based on solid scientific research, were subjected to environmental impact assessment, and were cross-evaluated to ensure synergy between each proposal. The combined objectives of these proposals were to lead to more effective protection of the rural aquatic environment and more efficient production of food. The revised nitrates regulations (SI610 of 2010, published by the Department of Environment, Heritage and Local Government on December 20, 2010) are a reflection of the power and effectiveness of strong scientific justification in effecting changes and improvement in policy. This article outlines how the revised regulations have incorporated many of the Teagasc proposals.

Lag times for response in water quality

The introduction of the nitrates regulations resulted in significant and sweeping changes in farm infrastructure and farm practices across the country, specifically in relation to nutrient management facilities and practices. Based on a comprehensive programme of field experiments, laboratory experiments and modelling studies, and supported by consensus in the large body of international scientific literature, Teagasc has forecast that the implementation of the nitrate regulations will have reduced point-source losses and incidental losses from agriculture to water significantly. Teagasc also expects significant reductions in diffuse phosphorus (P) and nitrogen (N) pressures and losses from agriculture to water over time.

While the regulations may have instantly reduced farm-gate P and N balances, the Teagasc submission highlighted how it may take years to decades for improvements in nutrient efficiency to translate into improvements in water quality. These delay periods are a result of biophysical constraints and are unlikely to be overcome by further and/or supplementary measures to manage nutrient source pressures. As a result of this, combined with water quality trends indicating gradual improvement, the outcome of the review has reflected this approach of allowing current regulations time to work before considering more restrictive measures. Teagasc's Agricultural Catchments Programme (see article on p.14) is specifically designed to scientifically assess the effectiveness of the regulations, even before improvements in on-farm nutrient management will have translated into improved water quality.

Tillage sector

The revised regulations have introduced considerable improvements for tillage farmers. Teagasc's proposals have been incorporated to adjust the maximum N application rates on winter wheat, as well as P allowances on all cereal crops, to better reflect nutrient requirements of these crops. Original requirements regarding green cover establishment after ploughing and non-selective herbicide use during autumn and winter months had also given rise to considerable practical difficulties for farmers within the regulations. Teagasc and international research has shown

that the risk of nitrate losses under arable land is low during the coldest winter months of December and January. This has now resulted in the regulations being changed to allow ploughing and/or non-selective herbicide use after November 30 each year without any requirement to establish a cover crop. This change from the previous date of January 15 will be a major improvement for farmers.

Organic fertilisers

There is a strong drive towards improving the utilisation and efficiency of nutrients that can be recycled in organic fertilisers such as animal manures. However, the Teagasc submission highlighted a number of ways in which the regulations were negating the benefits of organic fertiliser usage due to inappropriate assumptions of manure fertiliser N value. As a result, the revised regulations have been changed. Firstly, the assumed N availability of spent mushroom compost has now been reduced from 45% down to 20%. In addition, the inclusion of organic fertiliser application in the N-index system for tillage crops was also shown to overestimate the potential contribution of organic fertilisers to crop N nutrition. As a result, the N-index system for tillage crops is now no longer dependent on historic organic fertiliser applications.

These changes in organic fertiliser management regulations will mean that organic fertilisers will be more attractive as a nutrient source to farmers to offset chemical fertilisers. In particular, these changes will play a major role in allowing effective application of pig and poultry manures on tillage crops.

Grassland

The Teagasc submission focused in detail on the implementation of the P regulations in grassland systems. In particular, it highlighted a number of scenarios where P deficits may arise on farms due to negative farm P balances. The revised regulations have addressed these issues in a number of ways.

The assumption of the P content of concentrate feedstuffs has been made flexible in order to allow farmers to use more realistic P contents for the actual concentrate feedstuffs being used. This will improve the accuracy with which a farmer can account for inputs of P through concentrate feeds. The uncertainty associated with the fertiliser planning process caused by unforeseen variations in annual concentrate feed usage has also been reduced by allowing the concentrate feed usage of the previous calendar year to be used in the calculations of the current year. This means that farmers can be more certain in the planning process of the P requirements and application rates in the year ahead.

The P requirements for reseeded grassland have also been taken into account to reflect the additional P requirements of reseeded swards. This is a very significant outcome as farmers look towards improving the production and utilisation of grazed grass to exploit the competitive advantage of our low cost grass-based systems.

Implementation

Following extensive consultation with the Teagasc advisory network, a number of proposed amendments were submitted in relation to the operation of the nitrates regulations. In its submission Teagasc argued that simplifying the regulations would lead to a better understanding among farmers and, in turn, lead to higher rates of compliance. Solutions to the many significant practical and logistical challenges faced by farmers and advisers in implementing the nutrient regulations were presented in the submission. Many of these proposals have been taken on board, leading to a more streamlined implementation of the regulations.

There is a strong drive towards improving the utilisation and efficiency of nutrients that can be recycled in organic fertilisers.

Other changes

In addition to the changes that correspond to those proposed by Teagasc, the revised regulations have also incorporated a number of changes that reflect the concerns of the agricultural industry from an economic and social perspective. Changes that have been included, such as the extension of the transitional provisions for P applied in organic fertilisers produced by the pig, poultry and mushroom sectors, along with changes in the N allowance for spring barley, reflect the importance of these crops and sectors to the agricultural economy. The recent changes to the regulations are regarded as being positive for both Irish farming and the environment. Teagasc is continuing to develop its research programmes so that they will be in a strong position to inform the next review of the nitrates regulations.

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Securing Ireland's N derogation: the Agricultural Catchments Programme

In light of the targets for agriculture set out in *Food Harvest 2020*, securing Ireland's nitrogen derogation is more important than ever, say DAVID WALL and GER SHORTLE.

Securing Ireland's nitrogen (N) derogation will be a key component in facilitating the targets set out in the Department of Agriculture, Fisheries and Food's *Food Harvest 2020* of a 50% increase in dairy output and a 20% increase in the value of beef output. These increases in dairy and beef output could be achieved from existing agricultural land through increased grass production, carrying capacity and extending the grazing season. However, this extra output must be achieved in an environmentally sustainable manner, and is being supported by Teagasc through the Agricultural Catchments Programme (ACP).

Irish farmers have been working under the constraints of the Good Agricultural Practice for Protection of Water Regulations (nitrates regulations) since 2006. The aim of this suite of measures is to reduce N and phosphorus (P) losses in order to achieve the "good status" targets for our water bodies by 2015, as set out in the Water Framework Directive (WFD). The implementation period for the nitrates regulations was 2006 to 2009 and Member States are required to implement monitoring and evaluation programmes "to assess the effectiveness of action programmes".

The ACP is monitoring and evaluating the effectiveness of Ireland's National Action Programme, and is providing data to inform its review in 2013 and to support the continuation of Ireland's Nitrates derogation. The ACP is identifying, quantifying and assessing the management of nutrient sources on the farms and in the soils in a group of predominantly agricultural catchments.

Source compliance

The main aim of this programme is to evaluate the effectiveness of the nitrates regulations, with a view to providing scientific evidence to support the continued N derogation that has been granted to Ireland on a whole-territory basis. In order to manage nutrients correctly, knowledge of the type, quantity, origin and fate of the nutrients on the individual farms is needed. To facilitate this work, six agricultural catchments were established between 2009 and 2010, representing different farming types and environmental pressures. The catchments were selected on the basis of their perceived N or P loss risks, associated with the intensity and mix of farming enterprises, and their soil types and drainage characteristics. The goodwill and participation of the farmers was the most important factor in establishing these catchments and achieving good results from the programme. As with many agri-environmental studies, the ACP will initially provide a reference or baseline as a starting point to assess future progress.

Soil nutrient status

Following consultation with the farmers and landowners, a nutrient survey of the soils in each catchment was undertaken. Soil nutrient status (Morgan available P, K, lime requirement and soil organic matter) was audited on a field-by-field basis (or ≤2ha basis, whichever was the smallest). These data are providing information on both nutrient use compliance and also on the status of soils (for P in **Figure 1**). The focus in terms of soil P is to return high P soils (P index 4), which are perceived to be more risky in terms of P loss, to at least the upper boundary of P index 3, which is the agronomic optimum. Coupled with this information, soil nutrient input and output data are being collected on a continuous basis at farm and field level. For example, a dairy farm may have nutrient inputs consisting of fertilisers, feedstuffs and imported replacement stock, and nutrient outputs consisting of milk and exported stock. These data are being used to calculate nutrient balances for the individual catchments, and the farms and fields within them.

Correcting the balance

These high-resolution soil nutrient census and input-output balance data allow an evaluation of the long-term sustainability and potential impacts of the different farming enterprises and production systems. The ACP team of researchers and advisers are also using this data to develop strategies on individual farms to balance nutrient inputs with production levels, which is critical for developing longer-term nutrient management plans and strategies to meet future production targets. In the past poor distribution of P sources to fields has led to large ranges in soil nutrient levels over farms and wider catchment areas (**Figure 2**). Using soil test results to guide application of P sources will help to address these distribution and soil fertility issues. The soil nutrient concentration census forms the basis for strategies to correct nutrient balances at farm and field level and is critical for developing longer term nutrient management plans. Where elevated soil nutrient levels have been detected, it is important that the associated risk of nutrient losses is minimised in the future by careful management. In this situation, restricting nutrient inputs while maintaining optimum levels of production may help to minimise further losses and reduce the fertiliser input costs of this production. In contrast, where certain soil nutrient levels are suboptimal for the level of production intensity, losses of those specific nutrients may be minimised; however, there may be increased risk of other nutrients being lost (e.g., where soil P levels are suboptimal, N use efficiency may be reduced), as high levels of nutrient use efficiency relies on balanced soil fertility. In either situation, enhanced management and utilisation of the nutrient resources on farms will reduce both monetary and environmental costs.

Farm scale compliance

It is important for Ireland to be able to demonstrate compliance in terms of nutrient use, but also to be able to concentrate management effort in those fields where a legacy of intensive N and P fertilisation still exists. Equally, in terms of N use, P use and soil P compliance, it will be important to demonstrate how these nutrients are delivered to and interact with surface and groundwater bodies.

It is also important to investigate trajectories of water quality response, albeit with regard to the influence of other rural nutrient sources and rainfall-runoff patterns from year to year.

For both tillage and grassland farming systems, results from these catchments show that there is capacity to restrict soil P applications on index 4 fields and reallocate available P sources (especially organic manures) on the farms to the lower fertility fields (index 1-3), thus improving their fertility status.

However, knowledge and understanding of the soil–nutrient dynamics, and the influences of past nutrient management on current soil nutrient status, are important when deciding on the appropriate nutrient management options to be taken (both farmer and policy driven).

From a policy viewpoint, the data collected on soil P levels, and on nutrient use and balances in selected fields, will enable a prediction of the length of time required for soil P index 4 to reduce to optimum P index 3 (Schulte *et al.*, 2010). Currently, a farm facilities survey is being conducted on all farmyards within the catchments. This survey will detail the animal accommodation and will assess the over-winter storage requirements, organic manure storage requirements, organic manure management, and clean and dirty water handling facilities and management.

Looking to the future – sustainable, productive farming

With increases in agricultural outputs of milk and meat expected and the ever increasing costs of fertiliser inputs, it is now more important than ever to conserve and utilise available nutrient resources to their maximum. If farming can achieve this goal, it will be heading in the right direction to achieve the *Food Harvest 2020* and environmental goals under the Water Framework Directive. The ACP is well placed to help in this respect as its objective is to maintain sustainable, productive farming and environmental resources by:

- establishing baseline information on agriculture in relation to the nitrates regulations;
- providing an evaluation of the Good Agricultural Practice (GAP) measures and the derogation in terms of water quality and farm practices;
- providing a basis for a scientific review of the GAP measures with a view to adopting modifications where necessary;
- providing better knowledge of the factors that determine farmers' understanding and implementation of the GAP; and,
- providing national focal points for technology transfer and education for all stakeholders in relation to diffuse nutrient loss from agriculture to water.

The ACP is funded by the Department of Agriculture, Fisheries and Food with the Department of Environment, Heritage and Local Government as a major stakeholder.

Reference

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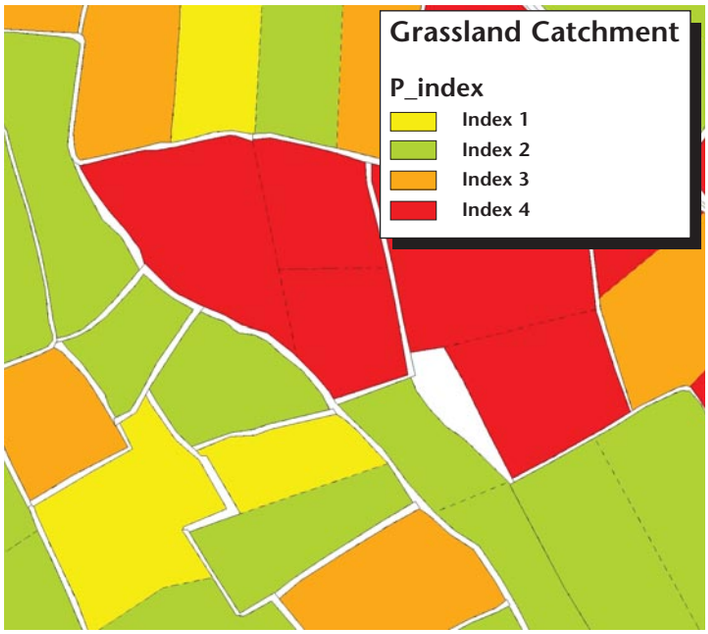

FIGURE 1: Spatial representation of soil P indices (soil P concentration ranges) across agricultural fields that were divided into approximately 2ha parcels for soil sampling.

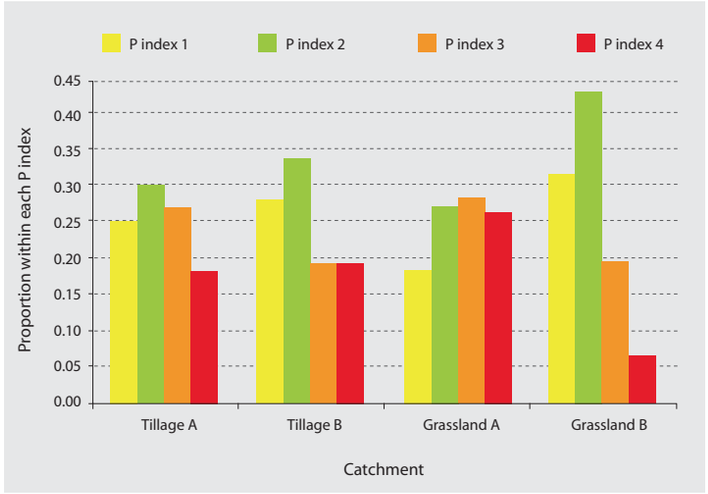

FIGURE 2: The area weighted proportion of soils within each phosphorus index for two tillage and two grassland catchments.

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Plant pathology diagnostics for horticulture

Teagasc's Plant Pathology Diagnostic Clinic for Horticulture aids in the management of plant diseases. BRIAN McGUINNESS and HELEN GROGAN describe the treatment of a recently emerging disease of the evergreen shrub *Escallonia*.

The Irish horticultural industry is currently worth approximately €360 million per year to the Irish economy (**Table 1**). It represents approximately 22% of all crop-based agricultural output and 6% of total agricultural output (Central Statistics Office, 2008). It provides over 6,000 jobs in the production sector and a further 9,000 in the amenity services sector; thus, horticulture is an important contributor to the Irish economy. The horticulture sector encompasses many diverse crops such as mushrooms, potatoes, field vegetables, strawberries and protected crops, as well as nursery stock and cut foliage. One of Teagasc's roles is to support the agri-food sector and the broader bioeconomy to ensure profitability, competitiveness and sustainability, and one of the ways this is achieved is through the Horticulture Plant Pathology Diagnostic Clinic.

Supporting Teagasc's horticulture clients

The Plant Pathology Diagnostic Clinic for Horticulture is based at Teagasc, Kinsealy, and provides a service to Teagasc's horticultural advisers and their clients around the country. When a problem arises within a crop such as poor establishment, poor yields, deformed growth, unusual symptoms or even plant death, an investigation is needed to identify the cause. Problems can be caused by a variety of factors, such as adverse weather conditions, pests, diseases or poor crop management, and solutions can often be found to correct the problem. When the underlying cause of the problem is identified, the adviser then works with the grower to eradicate it if possible. The majority of samples submitted are affected by fungal or bacterial pathogens that attack the leaves, stems or roots (**Table 2**).

The diagnosis of a problem with a specific plant requires in-depth knowledge of the pests, diseases and disorders that the plant can be subjected to. The Plant Pathology Diagnostic Clinic has an extensive range of literature and reference books on the identification of diseases, pests and disorders of crops such as mushrooms, strawberries, brassicas, carrots, onions, conifers and turf grasses.

Research solutions

Occasionally a problem presents itself for which there is no description or record in the literature to reach a diagnosis. Since 2006 an increasing number of *Escallonia* samples have been presented to the Clinic with severe leaf spotting and defoliation symptoms for which no information could be found. Thus it was necessary to carry out some research to identify the cause of the problem.

Escallonia leaf spot

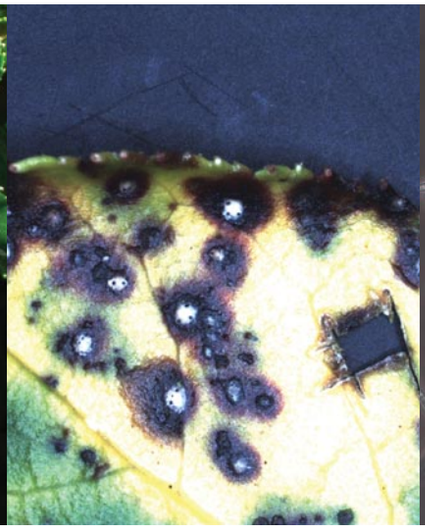
Escallonia species are evergreen shrubs with dark green leaves and pink flowers that are native to South America. They are generally quite hardy and trouble free and, as such, they are very popular with Irish growers. Since 2006, severe leaf spotting and defoliation symptoms have been reported for a number of *Escallonia* cultivars at various locations around Ireland – both in commercial nurseries and in private gardens. Plant stems and roots were unaffected but affected leaves gradually turned yellow and fell off the stems. Once the plants were defoliated, growth was reduced, and recovery and regrowth was slow. There were no reports in the literature of such a leaf spot disease on *Escallonia*, so some basic research was undertaken to identify the cause of the problem.

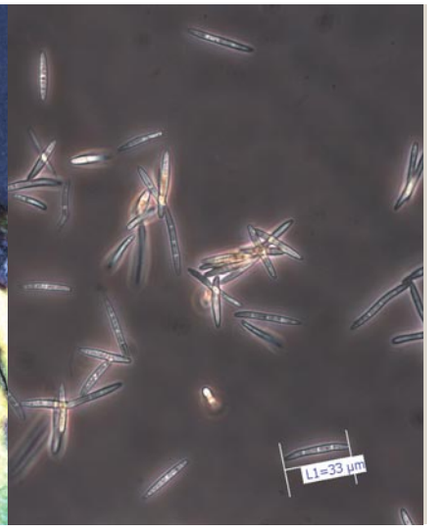
The leaf spots were 2-4mm in diameter, circular, and dark brown with centres turning paler. The spots had several dark brown to black globose structures (pycnidia) immersed in the plant tissue with an opening onto the leaf surface through which a tendril of fungal spores emerged. An asexual fungus was consistently isolated from the affected

Table 1: Farm-gate value of the Irish horticultural industry (2008).

Horticultural crop	Farm-gate value (€m)
Mushrooms	103
Potatoes	74
Field vegetables (including brassicas, onions, carrots)	59
Nursery stock*	31
Protected food crops (excl. soft fruit)	26
Protected soft fruit crops	23
Protected (non-food) crops	20
Christmas trees	10
Outdoor fruit crops	9
Outdoor flowers and bulbs	0.7
Cut foliage	2.7
Honey	1.0
Turf grass	1.5
Total	**€362m**

Source: Department of Agriculture, Fisheries and Food/Teagasc.
**Nursery stock figures have been recalculated to exclude traded imported material.*





From left: Escallonia rubra *var.* macrantha. *Image courtesy of Forest and Kim Starr; Close-up of leaf spot;* Ramularia *sp. conidia found on* Escallonia.

leaf spots, producing cylindrical/curved conidia (asexual spores) with two to four cells measuring 25-35 microns in length. This asexual stage was identified as being a *Ramularia* sp. and, although no sexual stage was observed, the sexual stage of a *Ramularia* sp. is usually a *Mycosphaerella* sp.

Molecular sequencing of the *Ramularia* culture isolated from *Escallonia* samples identified it as having a >99% similarity to the strawberry pathogen *Mycosphaerella frageriae*, a pathogen that causes similar leaf spotting symptoms in strawberries. There is a report of a *Mycosphaerella escalloniae* on a 1909 herbarium specimen of *Escallonia* in Argentina, but no *Ramularia* stage was described and no molecular sequence information is available.

Future research

At this point we do not know if our *Ramularia* isolates from *Escallonia* plants are the asexual form of *M. escalloniae* or *M. frageriae*, or if these two organisms are genetically identical. We do not know if strawberry isolates of *M. frageriae* can cause leaf spot symptoms on *Escallonia*. It is possible that the species or sub-species associated with *Escallonia* is different to that on strawberries, as pathogens are often very host-specific. Further research is needed to characterise different populations of *M. frageriae* from strawberry and Ramularia isolates from *Escallonia* to see how they relate to each other. Infection trials are planned using different isolates of *M. frageriae* from strawberry and *Ramularia* isolates from *Escallonia*. This should determine if there is a specific *Mycosphaerella* species associated with *Escallonia*.

Table 2: Main sample types and pathogens at the Plant Diagnostic Clinic.

Sample types		
Cabbage	Carrot	Cauliflower
Lettuce	Mushroom	Onion
Parsnip	Strawberry	
Nursery stock		
Box	Busy lizzy	*Dianthus*
Hosta	Leyland Cypress	Poinsettia
Thuja	*Viburnum*	
Pathogens		
Alternaria	*Botrytis*	*Cylindrocladium*
Downey mildews	*Itersonilia*	Mushroom virus X
Pestalotiopsis	*Phoma*	*Phytophthora*
Powdery mildew	*Pythium*	*Ramularia*
Sclerotinia	*Trichoderma*	*Various rusts*

Control

Mycosphaerella leaf spot fungi produce masses of asexual *Ramularia* spores on infected leaves. These are dispersed by rain splash onto adjacent leaves and plants where they can cause new spots to develop. Dead leaves accumulate on the ground over winter and they are usually the source of fresh spores in the spring. These are usually sexual spores produced from the *Mycosphaerella* stage of the fungus but we have no evidence yet of this stage occurring on Irish *Escallonia* plants. The summers in 2008 and 2009 were particularly wet and this was a contributing factor in the widespread occurrence of *Escallonia* leaf spot in recent years. In commercial nurseries fungicides can be applied to protect the young plants from infection but it is much more difficult to treat a large shrub or an established hedge. Shrubs and hedges can be pruned back and any dead leaf material should be cleared away. If wet summers persist then the problem is likely to re-occur but a few warm dry summers should allow hedges to recover.

Teagasc's Plant Pathology Diagnostic Clinic for Horticulture is funded by the Teagasc Core Fund. The unit will be moving to the Teagasc, Ashtown, site in 2012.

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Grass to energy and back again?

Researchers at Teagasc Crops, Environment and Land Use Research Centre have been looking at using waste from anaerobic digesters as a fertiliser.

In Ireland today, in excess of 90% of energy is imported. This imported energy is primarily fossil fuel, which is responsible for most of Ireland's greenhouse gas (GHG) emissions. In contrast, most Irish agricultural produce is exported, although some farmers are now considering alternatives to food production as a result of falling farm incomes. One popular alternative is farm energy production, e.g., by growing energy crops. Producing renewable energy within Ireland reduces our dependency on foreign imports and also reduces our GHG emissions.

Renewable energy from anaerobic digestion

Anaerobic digestion offers one possible way of generating renewable energy. This energy conversion technology converts waste material (such as slurries and manures) or energy crops (such as grass and maize) into biogas and a nutrient-rich waste material called digestate. Over 4,000 on-farm anaerobic digesters already operate in Germany, supplying renewable electricity to the German grid. Ireland's predominantly grass-based farming system produces considerable quantities of slurries and manures, from which energy could be extracted by anaerobic digestion. Grass also represents an excellent feedstock for anaerobic digesters, and can be harvested and stored using existing equipment and know-how.

Two projects are currently investigating the use of grass as a feedstock for anaerobic digesters in Ireland. The Greengrass project is co-ordinated by Teagasc's Animal & Grassland Research and Innovation Centre, Grange, with partners at University College Cork and Queen's University Belfast, and is investigating the extraction of energy and industrial products from grass. The Bio-GrAss project, which includes Teagasc's Crops, Environment and Land Use Research Centre, Oak Park, is led by University College Dublin and is investigating the GHG balance of grass-to-energy conversion. In the Bio-GrAss project, Teagasc is primarily involved in quantifying the fertiliser value and the GHG emissions of digestate as a fertiliser.

Digestate

The anaerobic digestion process converts carbon in the feedstock to biogas, which can subsequently be combusted to generate heat and electricity. This conversion process is carried out by bacteria, which convert more complex carbon compounds into simpler compounds. The process also releases nutrient elements previously bound up in complex organic compounds and thus unavailable for plant uptake when material such as slurry is used as a fertiliser. Thus, the anaerobic digestion process not only produces a nutrient-rich waste material that can be used as a fertiliser, but nutrient availability

in the waste material is higher than in the original feedstock. In cases where grass is used as a feedstock, digestate from the anaerobic digester can be returned to the grassland as a fertiliser, thus completing the cycle. There are two principal advantages to using digestate as a fertiliser. The first advantage is economic, as the cost of grass production is minimised because the cost of chemical fertiliser is eliminated or reduced. The question in this context is: what is the fertiliser value of digestate and how does it compare with chemical fertilisers?

GHG emissions from grassland

Apart from the agronomic advantages of closing the nutrient cycle and reducing costs, the second main advantage of using digestate as a fertiliser is that it has the potential for considerable savings in the GHG emissions from grass production. Considerable quantities of GHGs are released during the manufacture of nitrogenous fertiliser; these emissions are avoided when digestate is used as a fertiliser instead of chemical fertilisers. However, the effect of digestate on the nutrient cycle in the soil and GHG emissions thereof is not clear. While areas under grass are generally considered to be a net sink for atmospheric carbon dioxide (CO_2) until the soil is saturated with carbon, grasslands can also emit other GHGs like nitrous oxide (N_2O) and methane (CH_4). Emissions of N_2O are of particular concern, as this gas is 298 times more powerful in contributing to global warming than CO_2. Therefore, N_2O emissions during fertiliser applications are highly significant in GHG terms. Rewetting of dry soil, as well as freezing and thawing, have been identified as further events with potential for large N_2O emissions. CH_4 is another important agricultural GHG. Its global warming potential is 25 times that of CO_2. Agricultural soils, on the other hand, may act as net sinks for CH_4. The sink function is due to the oxidation of CH_4 to CO_2 by methanotrophic microorganisms in the soil, and has been reported to be greater for grassland than for arable soils. How does the use of digestate as a fertiliser affect GHG emissions from grasslands? This was another question that we wanted to answer.

Measuring greenhouse gas emissions after application at the Teagasc Crops, Environment and Land Use Research Centre, Oak Park. The metal chambers are used for measuring gas emissions.

Anaerobic digester at the Agri-Food and Biosciences Institute, Hillsborough, Co Down.

Our experiment

In order to quantify the fertiliser value of digestate and the GHG emissions arising from digestate application, we applied different quantities of digestate (thus different quantities of nitrogen [N]) to grass plots. Equivalent quantities of N fertiliser were also applied – either as calcium ammonium nitrate (CAN) or as urea. We applied digestate and fertiliser in three increments during each growing season, and measured GHG emissions before each application and for a long period after each application.

What we found

- Grass yield response to digestate as a source of N was similar to, though slightly lower than, that of chemical fertiliser.
- GHG emissions: There were no significant emission peaks that were not connected to fertiliser application, indicating that factors such as drying-wetting and freezing-thawing may be less important in Ireland compared to other countries. GHG emissions varied with year (i.e., meteorological conditions), as well as with fertiliser type.
- Fertiliser applications were followed by distinct GHG emission peaks, which declined over time. Emissions from CAN were almost ten times higher than from urea. Total GHG emissions from digestate application were lower than those from CAN but higher than those from urea.
- CH_4 fluxes: A small uptake of atmospheric CH_4 occurred in plots that received chemical fertilisers. Emissions of CH_4 were high in plots that received digestate due to CH_4 from the digestion process that was dissolved in the digestate. However, this peak decreased quickly and plots that received digestate became a sink for atmospheric CH_4 a few days after digestate application.

Benefits to industry

We found digestate from anaerobic digesters to be an effective N fertiliser, offering a similar N response to that of common chemical fertiliser. GHG emissions in the field from digestate were lower than for some types of chemical fertiliser but higher than others. However, a proportion of the GHG emissions after digestate application were attributable to dissolved CH_4, the main component of biogas, which is subsequently converted to energy. Thus, the GHG balance following digestate application can be improved by more efficient removal of CH_4 from the digestate, which will also improve the energy yield from the anaerobic digester.

Anaerobic digestion can turn waste products and energy crops into a fertiliser, as well as providing a renewable energy stream. The cycle is thus closed and nothing is wasted from the process. The use of this proven technology and its products thus becomes more attractive as Ireland moves towards a sustainable economy in which both fossil energy imports and GHG emissions are minimised.

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Acknowledgements

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Bioactives in minimally processed carrots

JUAN VALVERDE explains the impact of modified atmosphere packaging (MAP) on polyacetylenes in carrots.

In nature, polyacetylenes (PAs) are widely distributed and can be found in plants, fungi, lichens, moss, marine algae and invertebrates. More than 1,400 different acetylene-type compounds have been characterised in plants, and approximately half of these are PAs (Christiensen, 2010). Among higher plants PAs are common in several botanic families. PAs are commonly found in *Apiaceae* such as *Daucus carota* (carrot), *Pastinaca sativa* (parsnip) and *Petroselinum crispum* (parsley), which are commonly consumed as foods by humans. Recent studies and reviews have focused on PAs from carrots because of their interesting bioactive properties. In the plant, PAs have an important role in preventing fungal infections in the root, but when consumed as foods by humans, they could have some beneficial health effects. These include anti-bacterial, anti-inflammatory, anti-platelet-aggregatory, anti-fungal, anti-viral and anti-cancer effects (Christiensen, 2010).

In particular, PAs have lately been related to a reduction in the risks of developing diseases such as certain types of cancer and other important diseases (Christiensen and Brandt, 2006) and falcarinol has emerged as the most active PA in carrots in terms of cytotoxicity against cancer cell lines. The potential beneficial effects of PAs in human health have driven research into their characterisation and quantification in common foods such as carrot, celery, fennel and parsnip (Zidorn, 2005).

Preserving the quality of ready to eat vegetables

As part of the Irish Phytochemical Food Network, researchers at Teagasc Food Research Centre, Ashtown, are developing an understanding of how bio-active compounds in vegetables are affected by passage through the food chain, in order to optimise food quality. This knowledge can lead to better and healthier food products in terms of nutritional and functional quality. Modified atmosphere packaging (MAP) can be used to preserve ready to eat vegetable products such as carrot disks at point of sale during chill storage. Therefore, we were interested in assessing the impact of MAP and subsequent storage on levels of PA content in fresh cut ready to eat carrot products.

MAP is a technology commonly used in the food industry to improve shelf life. The process is based on trying to reduce the amount of oxygen (O_2) in a packaged food. The O_2 is often replaced by nitrogen gas (N_2), which already constitutes nearly 80% of air, or carbon dioxide (CO_2). The reduced amount of oxygen in the packaging precludes proliferation of bacteria and also oxidation. Carbon dioxide has shown good results on packaging meat and fish because it inhibits bacterial and fungal growth. However, fruit and vegetables need higher levels than 10% CO_2 to suppress fungal growth. At these levels CO_2 also has some negative impacts on fresh produce quality. Consequently, N_2 is commonly used as filler in fresh-cut fruit and vegetable products.

Polyactylenes and human health

PAs have been shown to have multiple bioactivity effects. The bioactivity of PAs can be classified in four groups, depending on the impact that they have on human health.

Anti-inflammatory and anti-platelet

The anti-inflammatory and anti-platelet activity of the falcarinol-type PAs is related to the ability of these compounds to react with nucleophiles and inhibit the activity of certain enzymes such as cyclooxygenases (COXs) and lipoxigenases (LOXs), which are responsible for inflammation and involved in tumour progression and atherosclerotic processes. Consequently, falcarinol-type PAs have a protective effect against the development of certain cardiovascular diseases, such as atherosclerosis. In addition, falcarinol has been shown to have an anti-platelet-aggregatory effect that seems to be related to its anti-inflammatory action (Christiensen, 2010).

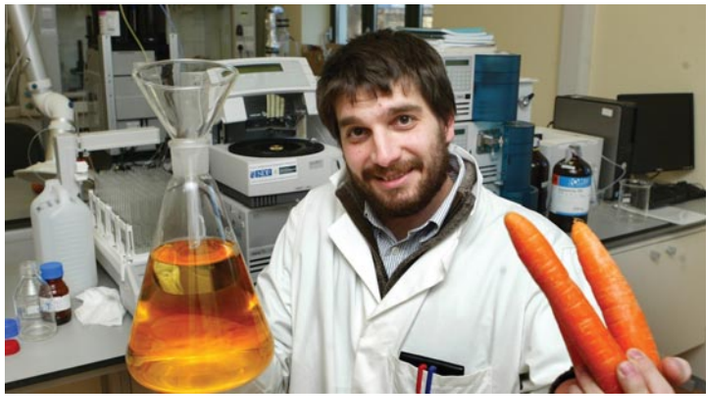
Anti-fungal and anti-viral

Falcarinol-type PAs are important anti-fungal compounds in carrots and other *Apiaceae* plant species because they inhibit spore germination of fungi. Several PAs have demonstrated anti-fungal activity against human pathogens, such as *Candida albicans*, *Microsporum* spp., and *Aspergillus fumigatus*. This anti-fungal activity has been demonstrated to be slightly enhanced by UV light (Christiensen, 2010). These effects have been highlighted as potentially interesting to use as food additives in order to avoid spoilage and improve shelf life, although little work has been done in exploring this potential (Christiensen, 2010).

Anti-bacterial and anti-mycobacterial

Recent studies have shown that C-17 PAs, such as falcarinol and falcarindiol, have antibacterial effects against various micro-organisms such as gram-positive bacteria (*Bacillus* spp., *Staphlylococcus* spp., *Streptococcus* spp.) and gram-negative bacteria (*Escherichia* spp., *Pseudomonas* spp.). These PAs also have anti-mycobacterial effects, of which the most important seems to be the activity against *Mycobacterium tuberculosis*.

These effects represent pharmacologically useful properties by which falcarinol and related PAs could have positive effects on human health, and may be used to develop antibiotics and innovative nutraceuticals/functional foods (Christiensen, 2010).



Dr Juan Valverde showing PAs extracted from carrots. (Image courtesy of Garreth Morgan, Irish Independent.*)*

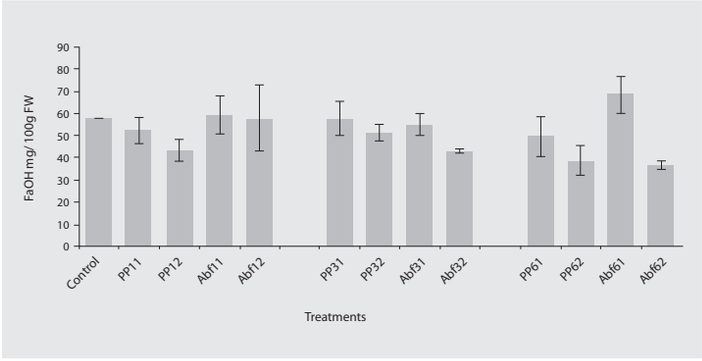


FIGURE 1: Falcarinol levels in carrots tested, where control stands for unprocessed carrots, PP for polyester-polyethylene, and Abf for alert breathable film; first digit represents day of sampling and second digit atmosphere composition.

Cytotoxicity and anti-cancer

Some C-17 PAs, such as falcarinol, panaxydol and panaxytriol, have been found to be cytotoxic against various cancer cell lines, such as leukaemia and human gastric adenocarcinoma. Falcarindiol also has cytotoxic activity, but it is less bioactive than falcarinol. It is still not known how these PAs work against cancer, but it may be related to the interaction with nucleophiles and various biomolecules. It has been suggested that one of the mechanistic pathways of falcarinol-type PAs is due to its ability to react with mercapto and amino groups from proteins, generating a hapten-protein complex, the so-called 'antigen' (Christiensen and Brandt, 2006).

Analysis of polyactylenes

PAs are usually extracted from fresh or dried material by a non-polar or low polarity organic solvent such as hexane, dichloromethane (DCM), ethyl acetate or acetonitrile. Prior to extraction, frozen samples are firstly sliced and then freeze-dried. This pre-treatment has been demonstrated to have no detrimental effects on bioactivity. Once the sample slices are completely dried, they are milled and vacuum packed. At this stage, PAs can be extracted effectively from the carrot powder. In the present study the extraction of PAs from dried powdered samples was carried out automatically using an accelerated liquid extraction. Separation and quantification was carried out using liquid chromatography.

MAP and polyacetylene content

The effect of MAP and subsequent storage on levels of PAs in carrots was investigated. Two 1.5kg batches of carrot disks were subjected to MAP using: Gas 1) 5% CO_2, 5% O_2 and 90% N_2; and, Gas 2) 10% CO_2, 80% O_2 and 10% N_2 as gas mixtures, using both: 1) polyester -polyethylene (PP); and, 2) alert breathable film (Abf), a polyamide-based breathable material, as the two packaging films. The packed samples were then stored at 4°C for six days. Levels of PAs were determined immediately at days 0, one, three, and six.

Benefits to industry

The results show that MAP is a useful way to retain PA levels in carrots. None of the three major PAs in carrots showed significant differences from the control. From the two gases used to modify the atmosphere for the storage of carrots, Gas 1 showed a better retention of falcarinol compared to Gas 2; this phenomenon may be due to higher amounts of O_2 present in Gas 2, leading to a higher rate of oxidation of falcarinol (FaOH). The Abf film showed better retention of falcarinol than PP; this is probably due to its permeable characteristics, which allow a higher moisture transfer rate. The other two major PAs from carrot were retained more effectively with MAP. No significant differences were observed over time when compared with control. Moreover, non-significant differences were observed between MAP treatments. Therefore, MAP seems to be a suitable packing for the retention of such bioactive compounds from carrots.

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'Next-generation sequencing' and food microbiology

Access to a state-of-the-art 'next-generation sequencing' technology at Teagasc Food Research Centre, Moorepark, will enhance the ability of Teagasc researchers to carry out groundbreaking investigations in a number of different areas.

While the race to sequence the human genome has attracted much attention and has increased the profile of DNA sequencing technologies, in the background this same technology has been applied in a multitude of other ways, including cancer research, evolution and ecology, microbiology, virology, and plant and agricultural technology. The scientific revolution in this area is as a consequence of dramatic advances in the technologies that allow researchers to sequence DNA, i.e., so-called 'next-generation sequencing' (NGS) technologies. Several NGS technologies are available, e.g., the Roche 454, Illumina GA, and ABI SOLiD.

Application of NGS

In recognition of this scientific revolution, and to take advantage of it from the perspective of research in the food and agriculture fields, Teagasc has installed the first, and to date the only, Roche 454 DNA sequencer (GS-FLX Titanium) in Ireland at its Food Research Centre in Moorepark (managed by Dr Paul Cotter and operated by Dr Fiona Crispie, with bioinformatic expertise provided by Dr Orla O'Sullivan). Access to this technology has enhanced and will continue to enhance the ability of Teagasc researchers to carry out valuable research in a number of areas, which vary considerably, from sequencing plant genomes to investigations focusing on cattle genetics. As it is impossible to adequately summarise the many ways in which this technology can be applied, this article will focus specifically on its use to carry out food research from a microbiological perspective. Such research has included: the sequencing of the genomes of starter bacteria (to identify metabolic pathways that are desirable with respect to food flavour and production); probiotics (to predict their behaviour in the gastrointestinal tract and to better assess how these can improve health); spoilage and pathogenic microorganisms (to identify weaknesses that can be exploited to improve control thereof); and, viruses/phage (to better understand how to prevent these from becoming a problem during food fermentations). It has also included approaches that allow scientists to examine complex microbial environments or 'microbiomes'. Indeed, the use of NGS has completely changed the way in which scientists study microbiomes. This is due to the fact that, despite their best efforts, microbiologists do not have the ability to grow (culture) all microorganisms in the laboratory and thus, in the past, have been capable of only seeing the 'tip of the iceberg', i.e., the (frequently small) proportion of these that can be cultured easily. While culturing can give a false impression of microbial composition of a particular environmental niche, alternative 'culture-independent' approaches involving DNA sequencing are unbiased, as these provide information about all of the microorganisms (microbes) present regardless of whether they can be grown or not.

To date there has been a particular emphasis at Teagasc on investigating and, where necessary, altering the microbiota present in the gut of the elderly, infants and obese individuals.

NGS of microbiomes for food and health

In recent years scientists have employed NGS to reveal the presence of weird and wonderful microbes present in extreme environments from the bottom of oceans to Arctic climates. While this research has attracted great interest, in many cases it could be regarded as the microbiological equivalent of a 'stamp-collecting' exercise with researchers competing to uncover the most unusual microbes. However, research of one of the most extreme environments, i.e., the human gastrointestinal tract (gut), contrasts in that it has the potential to impact hugely on the health of individuals. This is because microbes correspond to nine out of every ten cells in our body. Indeed, in the large intestine the number of microbes can be as high as 10^{11} (100,000,000,000) per gram. This collection of microbes is known as the human microbiome. This microbiome contains 100 times more unique genes than those present in our own genomes, and has a metabolic capability

equivalent to that of our liver. While everybody is aware that there are a number of gut microbes that can make us sick, the majority of gut microbes are harmless and, indeed, a significant number can have a positive impact on our health. It is now known that many (possibly greater than 70%) of the microbes present in the human gut have adapted to this environment so efficiently that they are no longer able to grow outside it and it has only been since the advent of NGS technologies that we have been able to properly appreciate what microbes are present in the gut and what they might be doing.

These roles include vitamin synthesis, the digestion and absorption of foods, immunostimulation, the control of disease-causing microbes (pathogens) and prevention of other diseases, human intestinal cell proliferation, and aiding bowel movements. Now, armed with this knowledge, researchers at Teagasc can add considerably to the health claims, and thus value, associated with existing foods, and design the next generation of functional foods by identifying ingredients that impact positively on the composition of our gut microbiome, and in turn our health.

NGS of gut microbiomes

While NGS-based research of gut microbiomes will ultimately benefit all members of the population, to date there has been a particular emphasis at Teagasc on investigating and, where necessary, altering the microbiota present in the gut of the elderly, infants and obese individuals.

The elderly gut microbiome

With respect to the gut microbiome of the elderly, Teagasc and University College Cork (led by Dr Paul O'Toole) collaborate on the Eldermet programme. The goal of Eldermet is to determine how the gastrointestinal bacteria influence, and are influenced by, diet, health and lifestyle in older Irish people, with a view to the eventual identification of specific food ingredients that improve the health of the elderly by modulating components of the gut microbiota.

The infant gut microbiome

The same principle applies to the gut microbiota of infants. Evidence exists that early colonisation of the infant gastrointestinal tract by microbes is crucial for the overall health of the infant. The infant microbiota is influenced by factors such as the mode of delivery, the maternal microbiota, antibiotic exposure and other factors. Significantly, one of the major influencing factors is whether the infant is fed breast milk or infant milk formula. Breast milk is the ideal food for infants and contains a number of components that promote a healthy gut microbiota. Thus, producers of infant milk formula would like to generate new and improved formulae that more closely resemble breast milk with respect to its impact on the infant gut microbiota. Ireland is a major player in the global infant formula industry, producing ~12% of global exports, and research in this area is of key importance with respect to maintaining, and further enhancing, Ireland's reputation in this area. It is thus notable that collaborative research between Teagasc (Dr Paul Cotter, Dr Catherine Stanton), UCC and Cork University Maternity Hospital is employing NGS technology to carry out research in this area.

The gut microbiome in weight gain and obesity

Finally, Teagasc (Dr Paul Cotter, Dr Kanishka Nilaweera) and researchers in the Alimentary Pharmabiotic Centre (APC; Dr Eileen Murphy, Professor Fergus Shanahan, Professor David Kearns and others) are building on recent international studies that have highlighted the role of the gut microbiome in weight gain and obesity.This research indicates that the microbial populations of some individuals more successfully enable these individuals to extract energy from food. Thus, these individuals are more susceptible to gaining weight than those with a 'lean' microbiota. Taking this logic a step further, the identification of dietary components, and in turn new functional foods, that can alter this gut microbiota to one that less efficiently extracts energy could be employed as part of a strategy to manage the weight of overweight and obese individuals, and is an important goal of the Teagasc team. Access to NGS technologies will allow Teagasc researchers to be at the forefront of research in these, and other, important research areas.

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MicroRNAs – a quantum leap for biology

MicroRNAs, a class of small endogenous non-coding RNAs derived from what was previously thought to be 'junk' DNA, are now recognised as major players in the regulation of gene expression. ATTIA FATIMA and DERMOT MORRIS explain.

We are now entering an age of understanding and discovery in biology that has been likened to the transition from classical Newtonian physics to relativity and quantum mechanics with its ever-increasing levels of complexity and regulation. Indeed, one of the more recent discoveries in molecular biology of non-coding RNAs (**Figure 1**) has been termed "the biological equivalent of dark matter – all around us but almost escaping detection".

Gene regulation

How genes are expressed and regulated is the central question in molecular biology, and our knowledge in this area has been expanding enormously over recent years, albeit with a huge increase in complexity. Transcription is the first step towards expressing a gene followed by translation into protein. However, translation does not always occur and protein expression is often poorly correlated with transcription. Regulation of gene expression includes the processes that living organisms use to regulate the way that information in genes is turned into gene products. In fact, gene regulation takes place at many levels; at the mRNA level (through alterations in splicing or the stability of the mRNA) and after translation (by modifications of proteins). These gene regulation mechanisms are becoming increasingly well understood. One such mechanism of regulation is RNA interference (RNAi).

This is a conserved sequence-specific gene regulation process that is involved in transcriptional, post-transcriptional, and translational repression by specific RNAs called non-coding RNAs (ncRNA), i.e., RNAs that do not encode protein. It is mediated by two types of regulatory RNA species, i.e., small interfering RNAs (siRNAs) and microRNAs (miRNAs). A lot of interest is now focussing on miRNAs, a class of naturally occurring, small non-coding regulatory RNA molecules, approximately 22 nucleotides in length, encoded in the genomes of animals and plants. This interest is reflected in the dramatic increase in the number of PubMed references to miRNA in recent years (**Figure 2**). MiRNA genes can be located within the intergenic regions between protein-coding genes, as well as the introns of protein- or non-coding genes or even exons. Mature miRNAs originate from 70- to 100-nucleotide hairpin pre-miRNA precursors, which are cleaved by the RNase III family of endonucleases, called Drosha and Dicer, into a duplex. One strand of the duplex is degraded while the other functions as mature miRNA (**Figure 3**). The single-stranded mature miRNA is then incorporated into an RNA-induced silencing complex (RISC), subsequently leading to repression of translation or degradation of the target mRNAs.

While miRNAs were first described in 1993, it is only in the last five years or so that their significance has been recognised. In humans, approximately 50% of genomic DNA is transcribed in RNA with 2% of this translated into protein and 98% non-coding (Zhang, 2008). It is currently estimated that miRNA genes constitute about 2% of the known genes, but that in eukaryotes more than 60% of genes may be regulated by miRNAs. Thousands of miRNAs have now been identified in various organisms, with 1,212 human, 668 bovine, 195 porcine and four ovine miRNA sequences currently deposited in miRBase 16 (www.mirbase.org).

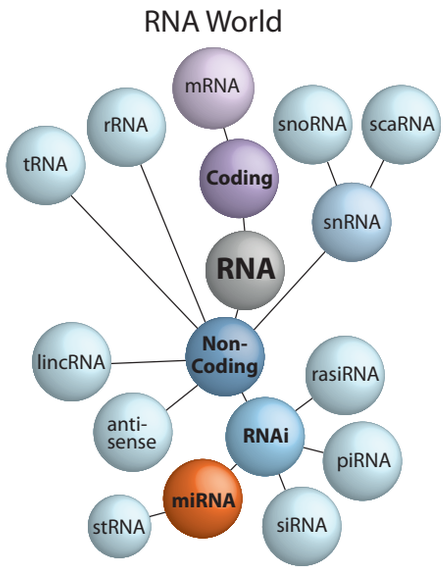

FIGURE 1: The RNA world showing miRNA and the many other classes of non-coding RNA (©Todd M. Smith, Geospiza, Inc.).

miRNA in development and disease

Several research groups have provided evidence that miRNAs may act as key regulators of processes as diverse as early development, cell proliferation and cell death, apoptosis, fat metabolism, and cell differentiation. MiRNAs are expressed ubiquitously across organs and tissues but many are tissue and species specific. Growing evidence shows that miRNAs are associated with a wide variety of human diseases. Various miRNAs have been linked to cancer and heart disease, and expression analysis studies reveal perturbed miRNA expression in tumours compared to normal tissues. MiRNAs circulate in a stable, abundant and cell-free form in the bloodstream and can serve as biomarkers of cancer and other diseases. MiRNAs are also rapidly emerging as attractive targets for disease intervention. Based on their unique properties miRNAs have been developed for *in vitro* evaluation of gene function, *in vivo* gene therapy, and generation of transgenic animal models. Results of these experiments suggest that the expression of miRNA target genes can be fine tuned in animals (and potentially plants) by altering the concentrations or identities of miRNAs within cells.

miRNAs and economic traits in livestock

Emerging research has indicated the importance of miRNA regulation of gene expression in many areas of economic importance in livestock, including reproduction, immunology, feed efficiency and milk production (Liu *et al.*, 2009). In fact, recent large-scale genome-wide studies have identified that differences in complex traits in many

species (such as production traits in livestock) are mainly associated with regulatory elements within genomes rather than protein coding genes as traditionally perceived. MiRNAs are expressed ubiquitously in all organs and tissues and miRNAs usually induce gene silencing by binding to target sites found within the three prime untranslated regions (3'UTR) of the targeted mRNA. Since most target sites on the mRNA have only partial base complementarity with their corresponding miRNA, individual miRNAs may target as many as 200 different mRNAs. Moreover, individual mRNAs may contain multiple binding sites for different miRNAs, resulting in a complex regulatory network. In recent years, a lot of effort has been invested in the role of miRNA in human development and disease progression; however, there has been little systematic investigation of their role in animal genomics and in regulating the expression of economically important traits and in disease.

Teagasc miRNA research

A number of bioinformatics-based projects are currently underway in Teagasc, with the aim of understanding the extent of association between allelic variants of miRNA (and their mRNA targets) and economically important traits such as growth rate, fertility, milk production and disease resistance in dairy and beef cattle. One of these studies is examining the association between miRNA and gene expression in an animal model of postpartum negative energy balance (NEB) in dairy cattle; to what degree miRNAs are responsible for the effects of NEB on gene expression seen in different tissues (Morris *et al.*, 2009; Wathes *et al.*, 2009; McCarthy *et al.*, 2010) and how this information may be used in a breeding programme to reduce the prevalence of NEB or to identify animals at risk.

Benefits to industry

Identifying SNP polymorphisms in miRNAs or in their 3'UTR targets and investigation of the association between these and economically important traits in beef and dairy cattle will increase our understanding of the complex molecular interactions that are responsible for these traits. These data could then be incorporated into the next generation of genomic evaluations where prior information of associations and, more importantly, the interactions between genes and regulatory elements, may be utilised to better reflect the complexity of biological systems.

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This research is funded by the Teagasc Core Fund.

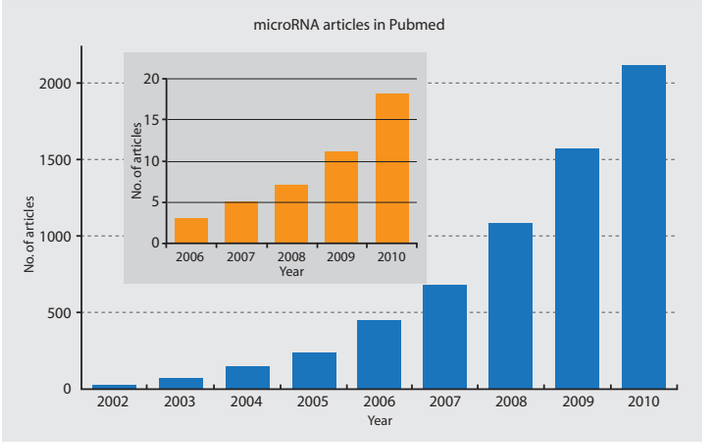

FIGURE 2: Total number of references to the term microRNA in the PubMed (titles and abstracts) database by year and (inset) number of references to miRNA in cattle, pigs and sheep – http://www.ncbi.nlm.nih.gov/pubmed/.

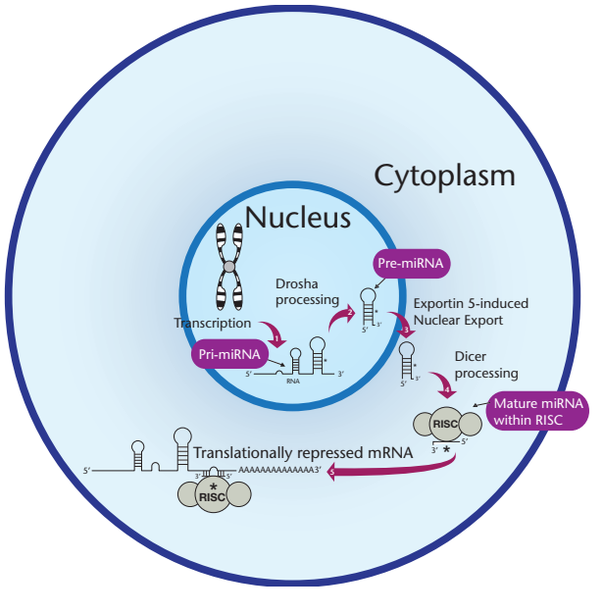

FIGURE 3: Mechanism of miRNA biogenesis and mRNA repression.

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High and low fertility in dairy cows

SEAN CUMMINS and DR STEPHEN BUTLER describe a genetic model of high and low fertility in lactating dairy cows. This is a valuable research resource to identify strategies for improving dairy cow reproduction.

Background to declining fertility

Historically, the Irish dairy herd was primarily comprised of the British Friesian. Ireland's first national selection index, known as the Relative Breeding Index (RBI), was established in 1990. The RBI was a single trait selection index, focusing solely on milk production traits. Selection Indexes that encouraged use of high milk production bloodlines were common at the time. Selecting solely for milk production traits had been carried out in the North American Holstein Friesian (NAHF) breed for decades. From 1990 to 2001 the proportion of NAHF genetics within the Irish dairy herd increased from 9% to 65%. In the same period, the average pedigree index for milk yield and actual phenotypic milk yield increased by 275kg and 742kg, respectively (Evans *et al.*, 2006). This so called 'Holsteinisation' of national herds occurred in most major milk production countries around the world. The NAHF cow was selected under high energy density total mixed ration feeding systems and total confinement housing, as is commonly practised in the US. However, in countries like Ireland that employ strict seasonal-calving pasture-based systems, diets consisting primarily of grazed grass reduced daily energy intake potential; *ergo*, energy intake was inadequate relative to potential for milk production. The resulting cows were susceptible to negative energy balance and excessive mobilisation of body reserves in early lactation, failed to regain body reserves during mid to late lactation, and had markedly depressed reproductive efficiency. The overall effect was to reduce the profitability of pasture-based systems. In 2001, the Irish Cattle Breeding Federation (ICBF) established a multi trait selection index to address the problem of declining fertility in the national herd, known as the Economic Breeding Index (EBI). As the name 'Economic Breeding Index' infers, the EBI is designed to identify genetically superior animals for profitability in typical Irish milk production systems. The genesis of a profitable cow is expressed in the EBI through six subindexes (relative emphasis): milk production (38.1%); fertility/survival (34.8%); calving performance (10.3%); beef carcass (7.2%); maintenance (6.1%); and, health (3.6%). The fertility subindex is comprised of calving interval (CI), which is the single biggest contributor to the EBI at 23.2%, and survival (11.6%). The trends in genetic merit for CI and survival of progeny-tested AI bulls during the last 40 years are illustrated in **Figure 1**. Deterioration in both fertility traits is evident from the early 1980s until around 2000, followed by a period of rapid improvement in the last 10 years.

Establishment of Moorepark High/Low fertility herd

To improve our knowledge in key areas of dairy cow reproductive physiology, a long-term project using cows with similar genetic merit for milk production traits, but with extremes of high (Fert+) or low (Fert–) genetic merit for fertility traits, was initiated in autumn 2007. In collaboration with the Irish Cattle Breeding Federation (ICBF), the national herd was screened for heifers of NAHF ancestry, calving for the first time in spring 2008. Within this population of heifers, large variation in genetic merit for fertility was apparent (**Figure 2**). Two populations of heifers with extremes for either high or low genetic merit for fertility were identified. Within these two populations, eligibility was restricted to only heifers with high genetic merit for milk production. Heifers identified as available for purchase were examined (size, body condition, lameness, etc.), screened for infectious diseases and subsequently moved to Moorepark Research Farm in their last trimester of gestation. On arrival, the high and low fertility animals were managed as a single herd in a typical grass-based spring-calving production system. By standardising genetic merit for milk production, proportion of NAHF ancestry and environment (i.e., management practices, diet), it was envisaged that the underlying physiological basis of declining reproductive performance in lactating dairy cows could be elucidated using this genetic model of high and low fertility.

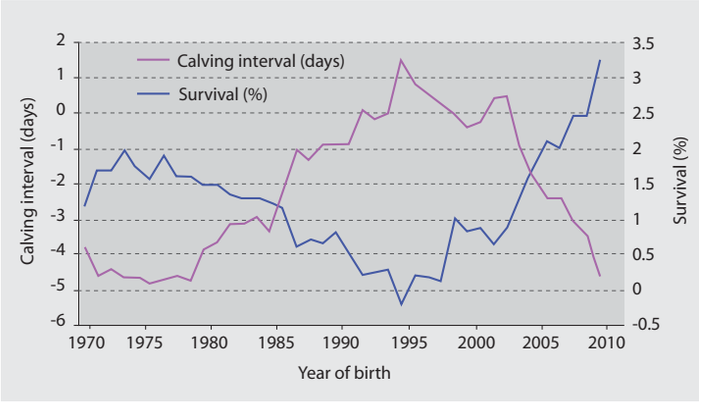

FIGURE 1: Genetic merit of progeny-tested bulls for fertility and survival traits. Source: www.icbf.com.

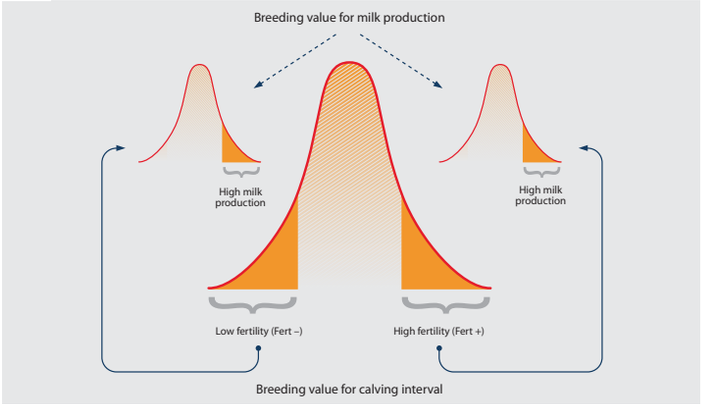

FIGURE 2: Heifers with high and low genetic merit for calving interval were identified. Within both groups, selection criteria were restricted to heifers with high genetic merit for milk production.

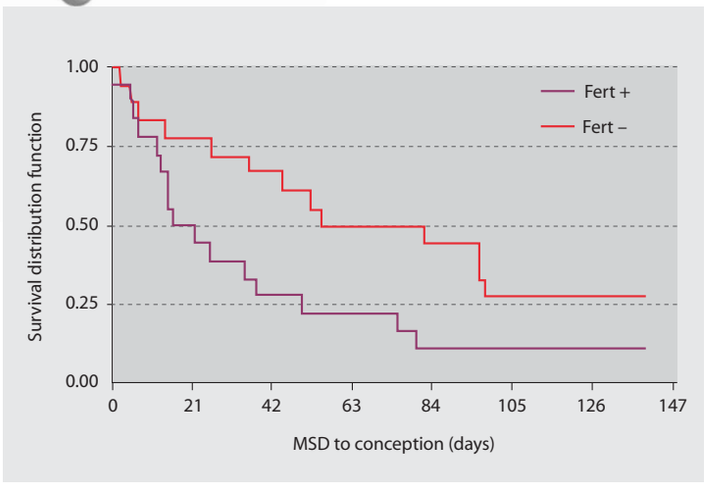

FIGURE 3: Survival analysis curve showing the interval from mating start date (MSD) to conception in high and low fertility cows.

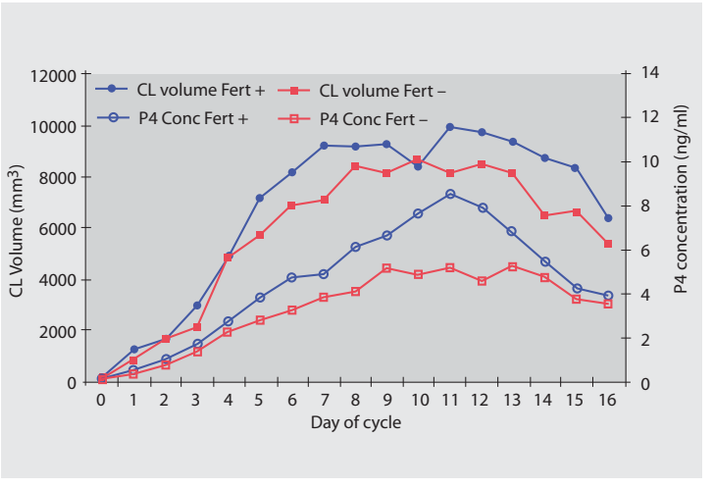

FIGURE 4: Temporal profile of corpus luteum volume and circulating progesterone (P4) concentrations during the oestrous cycle of high and low fertility lactating dairy cows.

Results to date

Validation of the genetic model

Following parturition, cows were turned out to grass in early February until mid November and grazed under a rotational grazing system. During the entire first lactation, mean milk production (17.6 *vs.* 17.7kg/day), milk solids yield (1.25 *vs.* 1.26kg/day), milk fat concentration (39.0 *vs.* 38.5g/kg) and milk protein concentration (33.1 *vs.* 33.6g/kg) did not differ between the Fert+ and Fert– groups, respectively. This indicated that the energy demands associated with lactation were similar between groups.

The breeding season commenced in mid April 2008 and lasted for 20 weeks. Cows were inseminated to observed oestrous to sires of their own genetic group to generate replacement heifers. There was no difference in the calving to service interval for both groups (averaging 77 days), but there was a large difference in the calving to conception interval, which is a vital statistic in a seasonal calving system. On average, Fert– cows took an extra 28 days to conceive, increasing the inter-calving interval to 395 days compared to 367 days for the Fert+ cows. The reproductive performance of both groups is best illustrated in a survival analysis curve (**Figure 3**), which plots the rate at which both groups successfully conceived. The y-axis is the proportion of animals not pregnant and the x-axis is the interval from mating start date (MSD) to conception. The Fert+ cows readily went in calf and would survive in a seasonal-calving system of production. Reproductive performance was suboptimal in the Fert– cows; these animals required more services to get pregnant (2.9 *vs.* 1.8) and had a higher non-pregnant rate (28% *vs.* 11%) at the end of the breeding season.

Large differences in reproductive performance were observed, indicating for the first time that phenotypic reproductive efficiency is critically dependant on genetic merit for fertility traits. However, the underlying physiological controls responsible for the observed differences in reproductive performance remained unknown. With this in mind a detailed study of ovarian dynamics was carried out on the high/low fertility herd in 2009, then in their second lactation.

Corpus luteum function

The function of corpus luteum (CL) is to produce progesterone (P4), a steroid hormone essential for pregnancy establishment. Following a synchronised oestrous, the Fert+ and Fert– cows underwent daily transrectal ultrasonography and blood sampling three times daily, with a view to monitoring CL volume and P4 concentrations throughout the duration of the oestrous cycle. The results are illustrated in **Figure 4**. The CL volume was larger and circulating P4 concentrations were greater in the Fert+ cows (depicted in blue) during the first 16 days of the cycle, compared to the Fert– cows. This is the first time genetic merit for fertility traits has been shown to alter both the size of the CL and circulating concentrations of P4. The results concur with a large body of evidence demonstrating the beneficial effects of elevated P4 concentrations on early embryo survival.

Benefits to industry

A unique genetic model has been established whereby animals exposed to similar energetic demands associated with milk production display large differences in reproductive efficiency, at least partially explained by differences in CL volume and circulating P4 concentrations. This study clearly demonstrates that it is possible to simultaneously select for improved milk production traits and fertility traits as part of a balanced breeding objective. This animal model represents a unique and powerful tool to improve our understanding of poor fertility and elucidate the critical events associated with pregnancy establishment.

This research was funded by the National Development Plan and the Dairy Levy Trust.

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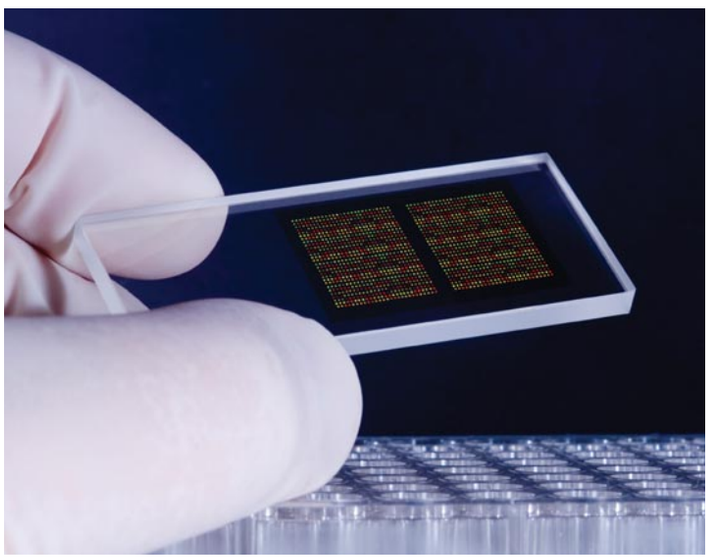
Recent advances in sheep genomics

The International Sheep Genomics Consortium heralds a new era in sheep genomic research. ORLA KEANE explains.



DNA chips used for high throughput genomics.

Genomics refers to the study of the complete genetic information of organisms. In the past 20 years a genomics revolution has taken place, with the generation of new genomic sequence data proceeding at an unprecedented pace. In addition to sequence data, new technologies such as genotyping platforms and microarrays have revolutionised animal genetics. Genotyping platforms, commonly known as single nucleotide polymorphism (SNP) chips, are small glass slides to which microscopic pieces of DNA have been attached. These chips are used to screen an animal's DNA for the presence of many genetic markers simultaneously. Microarrays also consist of DNA immobilised on a solid surface, and are used for the analysis of gene expression, i.e., which genes are switched on or off. Such technologies, which facilitate global analysis of genetic variation and transcript profiling, have led to the growth of functional genomics – a branch of molecular biology that ascribes functions to genes and genomic segments.

When the Human Genome Project was initiated in 1990 the sequencing of livestock genomes was not foreseen due to the high cost involved. However, such have been the advances in the technology that all the major domestic livestock species now have complete reference genome sequences available or genome sequencing projects underway. Traditionally, the small size of the international market for sheep (ovine) products has limited investment in sheep genetic and genomic resources and commercial sheep genomic resources have developed at a slower pace and to lower specifications than for other species of domesticated livestock.

International Sheep Genomics Consortium

The formation of the International Sheep Genomics Consortium (ISGC) heralds a new era in sheep genomic research. The Consortium is an international partnership of scientists and funding agencies whose goal is to develop public sheep genomic resources that will facilitate researchers to find the genetic basis for production, quality and health traits in sheep. Traditional gene mapping experiments in sheep used small numbers of families from research flocks with known pedigrees to map genes controlling traits of interest. As genomics advances and more genetic markers are discovered, a paradigm shift is taking place. Studies that genotype large numbers of individuals from the national flock for many SNP markers are now required. The ISGC, in collaboration with Illumina® (a commercial company that provides genetic research tools), developed a sheep genotyping platform consisting of a chip containing 50,000 evenly spaced SNP markers. This chip, termed the Ovine SNP50 BeadChip, was released in January 2009.

A reference sheep genome will greatly facilitate Teagasc researchers to map genes controlling traits of interest in Irish sheep populations.

Ovine BeadChip

The Ovine SNP50 BeadChip has already been put to work by sheep researchers both internationally and in Teagasc. The ISGC has used the newly developed SNP chip to genotype approximately 3,000 sheep of 74 breeds from around the world in the Sheep HapMap and breed diversity project. The sheep genotyped included approximately 50 each of the Galway and Suffolk breeds sourced from Teagasc and University College Dublin flocks. The technology also makes mapping the gene responsible for a single gene recessive trait relatively straightforward. Since the SNP chip was released, the technology has been successfully used to map and identify the gene responsible for microphthalmia (a recessive disorder causing blindness) and chondroplasia (a disease resulting in dwarfism and deformity of the limbs) in the Texel breed, yellow fat in the Perendale breed, and the gene responsible for polledness. As part of the FP7 3SR project (Sustainable Solutions for Small Ruminants), the technology is currently being utilised by Teagasc researchers, in collaboration with the ISGC, to map the gene responsible for increased ovulation rate in the highly prolific Cambridge flock at the Teagasc Animal & Grassland Research and Innovation Centre, Athenry.

Such examples of gene identification can have an immediate impact on the

Sheep genomics resources will aid the discovery of genes associated with economically important traits.

sheep breeding industry by allowing sheep breeders to screen animals for the genes and select replacement stock, cull or avoid at-risk matings based on the results. The technology is also currently being utilised by Teagasc and collaborators to identify genes underpinning polygenic traits, such as production traits and parasite resistance. Furthermore, the technology is a fundamental tool required for genomic selection, where animals are selected on genomic rather than phenotypic characteristics. The Irish Cattle Breeding Federation (ICBF), in collaboration with Teagasc, recently incorporated genomic selection into the national breeding programme for dairy cattle. The development of the above-mentioned sheep SNP chip opens the door for the first time to the application of genomic selection to the sheep industry in Ireland.

Complete sheep genome sequence

The ISGC has more recently turned its attention to the generation of a complete sheep genome reference sequence. For this project, both a Texel ram and ewe were utilised, generating a sheep genome sequence on a par with the cow genome and offering many potential applications in sheep research. This sequencing project is currently underway, with sequencing being carried out using a mixture of traditional and new high-throughput sequencing technologies. The first batch of sequence reads were deposited into the National Centre for Biotechnology Information (NCBI) in the USA in February 2010 and an initial assembly is expected in 2011. A reference sheep genome will greatly facilitate Teagasc researchers to map genes controlling traits of interest in Irish sheep populations.

Functional genomics and systems biology

Sheep functional genomics and systems biology are fundamental in elucidating the biological basis of complex traits and identifying genetic polymorphisms that underpin variation in economically important traits in sheep. As such, sheep genomics can have a profound effect on sheep farming in addition to providing important biological information that has application in other species. As genomic and sequencing technologies advance and the associated costs decline, it will become feasible to sequence the entire genome of individual animals to evaluate their genetic worth. Recent advances have ensured that genomic technology is no longer a limiting factor. Historically, genetic studies in sheep were constrained by the ability to develop, map and genotype new markers in a sufficient number of animals. These bottlenecks have effectively been removed by the work of the ISGC. Future achievements will be limited only by the availability of DNA samples from a sufficient number of animals with accurate phenotypic information. Accurate trait definition and phenotype recording must now be expanded to allow researchers to correlate traits of economic importance in the Irish sheep industry with genetic data and so exploit the technology to its maximum advantage. This will be particularly challenging for traits that are traditionally difficult to measure, such as disease resistance. However, the identification of genetic variation in sheep that confers improvements in animal health and productivity with less reliance on farmer or veterinary intervention holds great promise. Teagasc's unique mix of on-farm phenotypic data and genomic resources and expertise makes it ideally positioned to exploit the genomics revolution for the maximum benefit of both pedigree sheep breeders and commercial lamb producers.

This research is funded by the Teagasc Core Fund and by the EU Seventh Framework Programme 3SR project. We would like to acknowledge the contribution of the FP7 3SR partners and the ISGC.

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Can DCD increase grass dry matter production?

Researchers at Teagasc Animal & Grassland Research and Innovation Centre, Moorepark ask: can the nitrification inhibitor dicyandiamide (DCD) increase grass dry matter production?

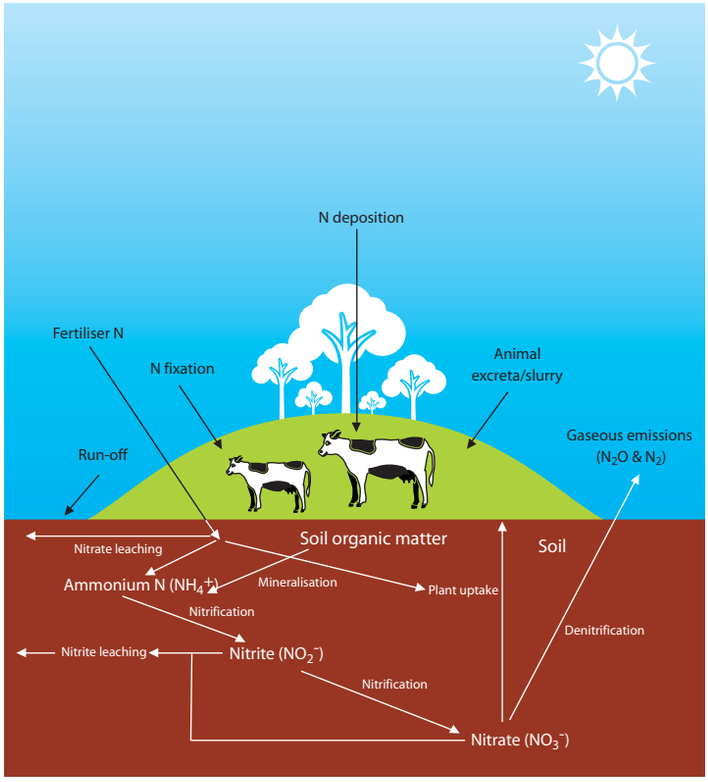

Figure 1: Schematic diagram of the nitrogen cycle in a farming system.

An extended grazing season is a key component of low cost animal production systems in Ireland. Increasing nitrogen (N) availability in spring can increase herbage supply for grazing. Spring N is usually supplied by chemical fertiliser or slurry. Urine and dung are also sources of N in grazed pastures (**Figure 1**). The N concentration under a single patch is high, equivalent to an application rate of up to 1,000kg N/ha (Whitehead, 1995). The quantity of N excreted exceeds grass demand for N and, therefore, the majority of this N is often lost by nitrate (NO_3^-) leaching or nitrous oxide (N_2O) emissions.

Nitrification inhibitors

Nitrification inhibitors are being investigated in Ireland, New Zealand and elsewhere as a strategy to reduce NO_3^- leaching and N_2O emissions. One such nitrification inhibitor is dicyandiamide (DCD), which slows the conversion of ammonium (NH_4) to NO_3^- by temporarily blocking the enzymes on the *Nitrosomonas* bacteria responsible for the first step in the nitrification process (Serna *et al.*, 1995). NO_3^- is readily taken up by growing plants, but if surplus NO_3^- is available, such as under urine patches or when plant growth slows during winter, it is likely to be lost through leaching. DCD has been shown to reduce NO_3^- leaching and N_2O emissions in New Zealand and in Ireland (Moir *et al.*, 2007; Dennis *et al.*, 2008). As well as reducing N losses, increased herbage dry matter (DM) production has been observed in New Zealand following the application of DCD in autumn and early spring (Di and Cameron, 2002; Moir *et al.*, 2007). To date, no work has been undertaken in Ireland to examine the effects of DCD on herbage DM production.

The efficacy of DCD is influenced by soil temperature. At 8°C DCD has a half-life of approximately 90 days, and at 20°C or greater the half-life is reduced to approximately 20 days (Di and Cameron, 2004). As a result, under Irish conditions DCD is most likely to be effective during the late autumn to early spring period. DCD is ideally applied to swards as a fine particle suspension (FPS) to maximise spatial coverage (**Figure 2**).

Herbage DM production experiments

Two experiments are being undertaken to examine the effect of DCD application on herbage DM production. The first experiment is examining the effect of applying DCD in late summer and early autumn (July, August and September) on herbage DM production at Moorepark (free-draining soil) and at Johnstown Castle (moderate drainage capacity). Artificial urine (urea and water mix) was applied to grass plots in July, August or September at a rate of 0 or 1,000kg N/ha. DCD was applied at a rate of 0 or 10kg/ha as a single application within 24 hours of urine application. Herbage DM production was measured every four weeks from July 2009 to June 2010.

Annual herbage DM production (July to June) was significantly ($p<0.01$) increased at Moorepark when DCD was applied to plots receiving urine in August and September by 15% and 9%, respectively, compared to when DCD was not applied (**Figure 3**). There was no significant effect of DCD on herbage production at Johnstown Castle. High soil temperatures in July reduce the effectiveness of DCD in slowing the conversion of NH_4 to NO_3^-, and naturally high grass growth rates at this time of year reduce the grass growth benefits that may occur from increased N availability. At Johnstown Castle, wet waterlogged soils in 2009 may have reduced grass growth, resulting in no effect of DCD or urine application.

The second experiment was undertaken at Moorepark on two contrasting soil types (free-draining at Moorepark and moderate to heavy soil at Ballydague Farm) over a two-year period. Artificial urine (as above) was applied to grass plots in September, October or November or not applied. DCD was applied at rates of 0, 5 or 10kg/ha as a single application within 24 hours of urine application, and a second application of DCD was applied to half the plots 90 days after the initial application. Herbage production was measured every four weeks from February to November.

In general, urine application increased spring (up to April) herbage DM production at both sites, and increased annual herbage DM production at Ballydague. DCD had little effect on herbage DM production during the

experiment. Applying DCD in November only, and in November and again 90 days later, tended to increase herbage DM production in spring of Year 2 on both soil types compared to other application times, but there was no effect in Year 1. This may be due to low rainfall during the December to February period of Year 2, combined with cold temperatures, which increased the efficacy of DCD and, therefore, increased N availability at the commencement of grass growth in spring. There was no significant effect of DCD rate (5 or 10kg/ha) on herbage DM production.

In addition to measuring herbage DM production, in both experiments soil sampling to a depth of 10cm was undertaken on a weekly basis for the first two weeks post application and less frequently thereafter to day 84 post application to quantify the NH_4:NO_3^- ratio in the soil. This data is still being analysed and, when this analysis is completed, will provide information on the efficacy of DCD in slowing the conversion of NH_4 to NO_3^- in the top 10cm of the soil during a 2.5- to three-month period post application. Herbage chemical analysis will also give an indication of the effect, if any, of DCD on N uptake by the plant.

Conclusion

Reductions in N_2O emissions and NO_3^- leaching observed by researchers at Johnstown Castle in other experiments (not reported here) indicate that DCD is effective in the soil. However, based on the herbage DM production data available from experiments to date, DCD does not have a large benefit in terms of herbage production (herbage production was only increased on a limited number of treatments on two experiments at three sites over two years). High rainfall in autumn in Ireland may be washing the DCD and the NH_4/NO_3^- on which it is acting beyond the rooting zone, and therefore the N is not available for plant growth. Soil analysis will provide information on the efficacy of DCD in the first 10cm of soil below the surface, a key area for N uptake by roots.

This research is funded by the Teagasc Core Programme.

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FIGURE 2: Sprayer to apply DCD as a fine particle suspension to grass plots.

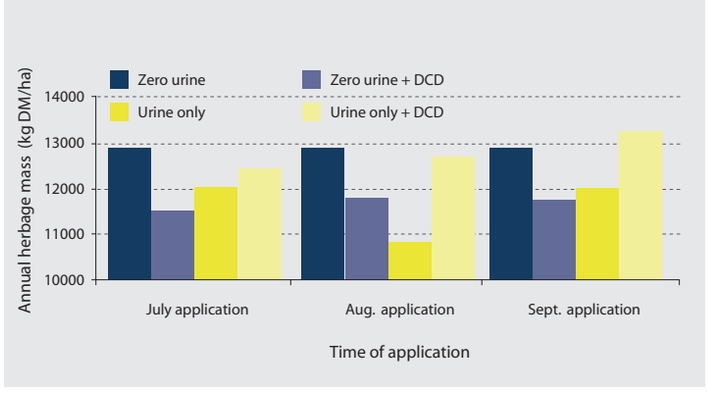

FIGURE 3: Annual herbage DM production (kg DM/ha) between July 2009 and June 2010 on plots receiving zero urine or urine applied in July, August or September with and without DCD at Moorepark.

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Volatility in agricultural markets: evidence, causes and possible solutions

The recent Teagasc Outlook 2011 conference had a session dedicated to price volatility; its causes, consequences and possible tools for its management. This article summarises some of the key issues raised at the conference.

Risk is an inherent part of agricultural production and it comes in a number of forms. The three main sources of risk in agriculture are: institutional, production and economic. The interaction between these different sources of risk is well established in the economics literature.

The demand for agricultural commodities is inelastic, which means that demand does not change very much as prices change. Food is a basic requirement for living and, in times of short supply, consumers will pay higher prices out of necessity. The short run supply of agricultural commodities is also inelastic but is more elastic in the long run. This means that producers would like to produce more when prices rise but it takes time for production decisions to result in final output increases. Thus, over the short run the supply of agricultural output tends to be fixed, which means that prices must adjust further to bring consumption in line with production.

In the past, large levels of global stocks addressed short-term production deficits and prevented an escalation in prices. However, global stock levels of many commodities have been lower in recent years than the historical norm.

Taking these factors together, the implication is that for a given level of demand small changes in supply can result in large short run price changes. The delayed response in production and substitution effects on the consumption side can then lead to cycles in prices. Thus, substantial price volatility can be expected to be a major characteristic of agricultural commodity markets due to the fundamental behaviour of buyers coupled with production uncertainty. Recent policy changes, such as reductions in price supports and export refunds, have resulted in European farmers being more exposed to movements in world prices. Price variation is desirable in terms of providing price signals that reflect changing market conditions, which lead to changes in resource allocation. Nevertheless, the principles of economics suggest a set of mostly negative consequences of extreme price volatility for producers (Keane and O'Connor, 2011). Most notably, extremely low prices can threaten the solvency of the farm unit. Very high prices, however, can also be problematic, in that they can result in product substitution on the consumption side (consumers forego a product whose price has risen in favour of a cheaper alternative), which can, ex post, be difficult or impossible to reverse. The exceptional price volatility in several agricultural commodity markets in recent years is creating problems for processors, farmers and other food supply chain participants. Thus, the consequences of price volatility and the need for tools with which to manage the associated risk is now a central issue for the food supply chain itself and for public policy.

Review of agricultural commodity market price volatility

Price volatility can be defined as a directionless measure of the extent of the variability of a price (Keane and O'Connor, 2011). Here, volatility is analysed using monthly price data. **Figures 1** and **2** show the volatility in the Irish farm gate milk price (actual fat and protein) and, in the absence of comparable data for Irish grains, the UK feed wheat futures settlement spot prices from 1992 to 2010. Given that Irish cereals market prices are highly influenced by happenings in the UK market, it is

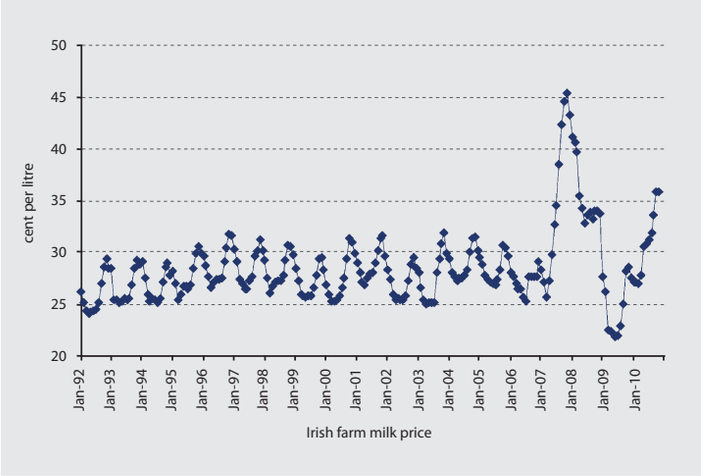

FIGURE 1: Irish farm gate milk price (1992–2010). (Source: Keane and O'Connor, 2011.)

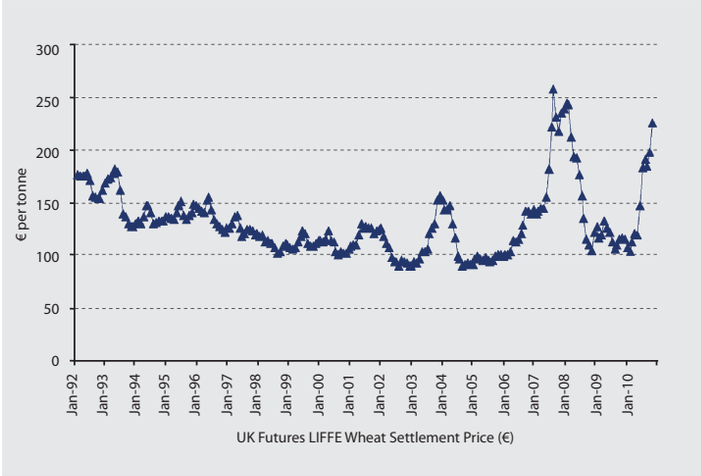

FIGURE 2: UK wheat futures spot prices (1992–2010). (Source: Thorne, 2011.)

Table 1: Descriptive statistics for milk and wheat price (1992-2010).

	UK LIFFE wheat price (€) per tonne	Irish farm gate milk price (c/l)
Jan 1992 to Dec 2010		
Mean	131.87	28.52
Standard deviation	31.89	3.65
Coefficient of variation	24.18	12.79
Jan 1992 to Dec 1999		
Mean	135.75	27.50
Standard deviation	19.99	1.85
Coefficient of variation	14.72	6.73
Jan 2000 to Dec 2010		
Mean	129.19	29.28
Standard deviation	38.11	4.39
Coefficient of variation	29.50	14.98

likely that volatility in the Irish market followed a similar pattern to that presented for the UK. Prior to 2007 there was virtually no evidence of extreme price volatility for farm gate milk price in Ireland (**Figure 1**). However, post 2007 it is clearly evident that volatility has become a major feature of the market. While volatility was more apparent in the wheat market prior to 2007, since 2007 volatility has also greatly increased (**Figure 2**). To further examine this volatility, a number of statistical approaches are used. The mean, standard deviation (SD) and coefficient of variation (CV) are the statistics commonly used to measure volatility (**Table 1**). The CV of a price series expresses the variability of the series relative to the average value of the series. This permits comparison across commodities. While the wheat price series displays greater SDs, caution is required as each of the series has different mean values and thus the CV is the more appropriate metric. The much larger CV reported for the wheat price series clearly shows the greater volatility associated with these prices. To examine the change in volatility over time, the time series was divided into two time periods, pre and post 2000. Comparing market price volatility for the milk and wheat price series described above for the two time periods, it was found that the CVs had approximately doubled for both prices between the two periods.

Causes of the increase in volatility

The price volatility in recent times is associated with several factors. The most important drivers of the increased volatility are the recent unanticipated shocks to supply when combined with low stock levels and inelastic demand. Over the last few years, this has been further accentuated in an EU context by major policy change (the Luxembourg Agreement), which increased the exposure of EU producers to market prices and the global recession that has affected the demand for agricultural commodities. Another possible factor, which has received considerable attention in recent debates, is the increase in volatility in commodity markets due to market speculation via hedge funds and index traders.

What options are available to deal with or reduce volatility?

There are a broad range of instruments, both in the public and private market, which may be utilised to manage price and income volatility. With regard to the private market, the available suite of instruments includes over the counter (OTC) contracts, forward contracting, futures contracts and insurance contracts. Examples of these private market measures include the Glanbia milk pricing scheme announced in late 2010 and grain forward contracts, which have operated for some years in the Irish industry.

Private market instruments require high quality, timely, objective and transparent market information, which needs to be easily sourced and freely available. There would appear to be a particular role for the European Commission in this regard. The free data dissemination provided by the United States Department of Agriculture and US extension colleges provides a useful template as it surpasses the data available in the EU in terms of its range and quality. It is desirable that, in the interim, some counter cyclical public policy instruments are maintained in order to moderate the effects of high price volatility.

The issue of volatility was specifically discussed in the European Commission's post-2013 communication published in November 2010 and in the paper from the High Level Group for Dairy, which was published in June 2010. Specific proposals from the European Commission on agricultural price volatility, expected in 2011, are awaited with much interest. However, it should be acknowledged that such measures should not inhibit the development of private instruments as may have happened to some extent in the US.

The full conference proceedings are available at: http://www.agresearch.teagasc.ie/rerc/downloads/Outlook2011.pdf.

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Farm diversification in Ireland

David Meredith reports on the nature of farm diversification in Ireland and compares it with diversification in England.

Eleven percent of English farms have a sport or recreation-based enterprise.

Farm diversification is concerned with improving the capacity of the farm, or farm resources, to meet the immediate and future needs of the farm household. Many farm households in Ireland depend on off-farm employment to maintain the viability of the farm business. The economic crisis has, however, resulted in reduced off-farm employment opportunities. Increasing numbers of farmers and their spouses have lost their jobs. Recent data produced by the Teagasc National Farm Survey established that the percentage of farm households with an off-farm job declined from 58% in 2007 to 53% in 2009 (NFS, 2010). The value of off-farm work to farm households has also declined from an average of €25,200 to €24,700 over the 2007-2009 period. This reflects the loss of relatively high-paid employment and cuts to the salaries of those who have managed to retain their jobs.

Supporting farm families

Studies undertaken by researchers working in Teagasc's Rural Economy Development Programme (REDP) identified the potentially negative impacts of a decline in the rural economy between 2005 and 2007 on off-farm employment (Walsh and Mannion, 2005; O'Brien and Hennessy, 2006; Dillon *et al.*, 2008). In response to the findings of this research, Teagasc developed a new integrated rural enterprise service for clients. The primary aim of this service is to encourage and support farm households to develop new enterprises on their farms. As part of this service, the REDP has been undertaking additional research to establish the number and type of farms with diversified enterprises (DEs) in Ireland.

Diversified farm enterprises in Ireland

The Farm Structures Survey in 2007 found that 5,000 farms in Ireland had some form of on-farm DE. This equates to slightly less than 4% of all farms in Ireland at that time. In the same year, a report to the British Government found that 29,200 farms (51%) in England had at least one DE. At first glance it seems that English farm households are more likely to diversify. Before coming to the conclusion that Irish farm households are less likely to diversify, a number of issues need to be considered.

... compared to England

In any comparative study of diversification, it is important to understand how this activity is defined. In England they count only "the entrepreneurial use of farm resources for a non-agricultural purpose for commercial gain". This excludes activities such as forestry, energy crops and contracting. Combined, these types of diversified on-farm businesses account for 2,500 or half of all DEs in Ireland. If we excluded these from the Irish data the proportion of farms in Ireland with a DE falls to 2% compared to England's 51%.
Closer consideration of differences in types of activities finds that the most common form of diversification in England is renting out buildings for non-agricultural use. Strict planning legislation in England precludes much new building development in the countryside.

It should also be borne in mind that many of the people living in Ireland's rural areas commute to work in towns and cities. Access to this type of employment effectively means that there is relatively more money in the rural economy to support DEs in Ireland compared to England.

For farmers in England this represents a significant opportunity as they are among the few businesses with sheds and buildings that are required by other rural entrepreneurs to develop and grow their enterprises. By comparison to England and other EU countries, Ireland's planning system facilitates new commercial buildings in rural areas, with the result that this type of diversification opportunity is unavailable to most farmers here. However, even

Farmers' market: there is relatively more money in the rural economy to support DEs in Ireland.

Table 1: Number of farms with diversified enterprises in Ireland and England.

	Ireland[1]	England[2]
Number of farms	128,200	57,100
With diversification	4.1%	51%
With farm tourism	0.94%	5%
With sport or recreational enterprise	0.39%	11%
With processing*	0.40%	7%
With other diversification**	0.78%	8%
With buildings let out	N/A	36%
With contracting	1.95%	N/A

[1] Central Statistics Office (2007) Farm Structure Survey. Dublin: Stationery Office – Table 41, page 79

[2] Keep, M. (2009). Farming diversification in England: statistics. London: House of Commons Library – Table 4, page 5

**Wood processing and fish farming are included under 'Processing'.*

***Other includes home crafts and renewable energy.*

when farmers renting out buildings are excluded, 31% of all farms in England have a DE. Arguably, another important difference is the size of England's population, which in 2007 stood at just over 51 million persons, compared to Ireland's 4.3 million. Clearly the English population represents a much larger market into which farmers can sell diversified products and services. Excluding the renting out of buildings for non-agricultural use leaves 18,200 farms in England with a DE. A comparison of the number of diversified enterprises finds 0.36 DEs per 1,000 population; the equivalent figure for Ireland is 0.58.

A further factor that may influence diversification rates in Ireland and England is the level of urbanisation. Urban populations, on average, have higher levels of disposable income and so, theoretically, are in a position to support DEs. Analysis of population distribution data established that 65% of Ireland's population lives in towns and cities (places with populations in excess of 5,000 persons), the equivalent figure for England is 80%. It is possible that the higher proportion of people living in urban areas accounts for the greater number of farms with a DE in England. Against this, however, one has to counterbalance the argument by recognising that the potential local market for DEs is smaller in some parts of England. As much of Ireland's population lives in rural areas this could be construed as presenting farmers here with greater opportunities to develop DEs. It should also be borne in mind that many of the people living in Ireland's rural areas commute to work in towns and cities. Access to this type of employment effectively means that there is relatively more money in the rural economy to support DEs in Ireland compared to England. Analysis of disposable incomes in rural areas of Ireland and England support this argument. In 2005, the most recent year that income data is available for Ireland, rural households had, on average, a disposable income of €796 while their counterparts in England had €760.

Conclusion

This analysis demonstrates that the actual rate of farm diversification is lower in Ireland compared to that of England. In order to encourage more farm households to consider diversifying their enterprises, the Rural Economy Development Programme in partnership with local development companies organised a series of events for Teagasc clients highlighting the services of the Options Programme. Over the course of 10 nights in excess of 1,600 farmers attended these seminars. This level of interest demonstrates that there is significant demand from farm families for information on new income-generating activities. It also supports preliminary findings from ongoing research, which indicates that 45% of farmers are favourably disposed to diversifying their enterprise.

Acknowledgement

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Walsh, J. and **Mannion, J.** (2005). 'Rural Ireland 2025: Foresight Perspectives'. Teagasc: Dublin – http://www.teagasc.ie/publications/2005/20051216/rural_ireland_2025_foresight_perspectives.pdf.

David Meredith is a Senior Research Officer with the Rural Economy Development Programme based at Teagasc in Ashtown, Dublin 15.

T Events

2011

MARCH

March 11 — *UCD Agriculture and Food Science Centre*

Soil Science Society of Ireland Spring Meeting

Topics at this meeting will include: overview of the Irish Soils Information System (ISIS) project; digital soil mapping in support of the ISIS; hyperspectral data and soil geochemical properties; hydrological lag time and the Water Framework Directive; managing our soils for food production and clean water: Agricultural Catchments Programme; nutrient management strategies to reduce phosphorus loss from agricultural soils; soil phosphate analysis on promontory forts; soil biodiversity in Ireland: the CréBeo Project; and, nutrient losses from grassland soils of contrasting drainage receiving dairy soiled water.
sharon.orourke@ucd.ie

March 14 and 15 — *Tullamore, Co. Offaly*

Agricultural Research Forum

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

APRIL

April 5 — *Cillin Hill, Kilkenny*

National Beef Conference 2011

Speakers will explore opportunities for Irish beef producers and outline the steps necessary to achieve profit from beef at farm level. Topics covered will include: future outlook for Irish beef production; getting the most from grazed grass; herd health for maximum performance and profitability; and, breeding efficiency and breed improvement in beef herds. The potential for AI use on suckler farms to increase production and quality in the beef herd will be highlighted. A live exhibit of AI progeny, along with an open discussion forum, promises to make this event one not to be missed.
http://www.teagasc.ie/events/2011/20110216b.asp

April 20 — *Tullamore Court Hotel*

Bio Energy Conference

The 2011 National Bioenergy Conference is jointly organised by Teagasc, DAFF and SEAI. The conference will look at the policy options for heat, electricity and transport with the introduction of a new government. Talks on anaerobic digestion, willow chip drying, the potential of bioenergy to sequester carbon and Ireland's biomass resources quantified will be presented followed by a one-hour panel discussion with key industry personnel focusing on bioenergy development options to meet Ireland's challenging 2020 energy targets.
liz.osullivan@teagasc.ie 059-918 3483

MAY

May 25-26 — *Ferrycarrig Hotel, Wexford*

Conserving Farmland Biodiversity: lessons learned & future prospects

The conservation of farmland biodiversity is a priority environmental goal in the *Food Harvest 2020* report. There will be strengthened emphasis by EU policies to halt biodiversity loss by 2020. A key aim of this conference is to address: how will the agriculture sector respond to these policy objectives? The conference will present the latest evidence and research on current and emerging practices and policies that affect farmland biodiversity. Priority themes will include: identification and management of high nature value farmland; analysis of current and forthcoming policies on biodiversity and agriculture; and, socio-economics of farmland biodiversity.
john.finn@teagasc.ie

JUNE

June 8 — *Teagasc Moorepark, Fermoy, Co. Cork*

Research Results on Alternative Non-Landspreading uses for Pig Manure

Nicola Pierce 025-42480 nicola.pierce@teagasc.ie

SEPTEMBER

September 4-8 — *Dublin Castle Conference Centre*

International conference: Eucarpia Forage and Amenity Grasses Section Meeting

The theme of the meeting is 'Breeding strategies for sustainable forage and turf grass improvement'. Over recent decades many developments in science and technology became available for application in breeding. Advances in tissue culture, cross species hybridisation, quantitative genetics and computational power, and biotechnology all have enormous potential, and are all being used with great success. This conference will ask the question: "What will the future of forage and turf grass breeding look like?"
susanne.barth@teagasc.ie www.eucarpia.org

September 12-15 — *Dublin*

7th International Conference on Predictive Modelling of Food Quality and Safety (ICPMF7)

This conference will bring together leading academics, research scientists and food professionals who are currently developing and using simulation and optimisation tools to enhance the quality and safety of food. This event also aims at attracting various stakeholders throughout the food chain, including policy makers and international authorities. On September 16, a collaborative EU Framework Project Seminar will be held.
www.icpmf.org/2011

September 14-16 — The Mansion House, Dublin

Catchment Science 2011

Catchment scale research and evauation for agriculture and water quality. This international conference is aimed at scientists, policymakers, farmers and managers. Jointly hosted by the Irish Agricultural Catchments Programme (Teagasc/DAFF) and the UK Demonstration Test Catchments Projects (Defra/EA).
catchments@teagasc.ie — www.teagasc.ie/catchmentscience

September 28-29 — *Teagasc Food Research Centre, Moorepark*

Cheese Symposium 2011

This conference will address the most recent fundamental and applied scientific research developments in the areas of flavour development and diversification, health and nutrition, and fat and/or salt reduction in cheese. It will provide a forum for academia and industry to share experiences on the latest developments and applications of cheese research. The programme will appeal to all involved in cheese research or production. A book of abstracts of all oral and poster presentations will be available on the day and selected oral presentations will be published in the *Journal of Dairy Science and Technology* at a later date.
Niamh O'Brien 025-42313 cheesesymposium2011@teagasc.ie

OCTOBER

October 10-12 — *Burlington Hotel, Dublin*

4th International Symposium on Animal Functional Genomics

This Symposium will provide an exciting opportunity for scientists working across a wide range of disciplines to meet and discuss the latest groundbreaking developments in the fast-moving field of animal functional genomics. Topics will include: application of new genomics technologies; computational biology and bioinformatics; and, systems biology. The Symposium is targeted to academic researchers, industry scientists, policy makers and regulators who wish to learn about the latest developments in basic and applied animal functional genomics research.
http://isafg2011.org/isafg_announcement.pdf