Technology Village

Innovations in plant breeding

Notes:

Technology village: Innovations in plant breeding

Our technology village at this year's Crops Open Day will provide an overview of research and development work carried out at Oak Park in support of plant breeding. Plant breeding has been a major contributor to agricultural productivity over the last fifty to sixty years. Breeding improved varieties of crop plants is a cost-effective strategy for reducing inputs, while maintaining or increasing yields. Teagasc breed new varieties of perennial ryegrass, white and red clover, and potato, and these breeding programmes are supported by research into improved breeding methodologies, and the development and deployment of new breeding tools. Teagasc also conducts pre-breeding research in a range of cereals and legumes in support of breeding varieties that will thrive under Irish conditions. Given the challenge to produce more from less and ensure our crops are resilient in the face of a changing climate, it is now more important than ever that the latest technologies are utilised to breed resilient crops. Our technology village will highlight a selection of these innovations:

- **Virtual Irish Centre for Crop Improvement (VICCI)**
  - an overview from *Dan Milbourne* on the latest research in VICCI, which brings together plant scientists across Ireland to address key challenges affecting Irish agriculture
- **Rapid development of DNA tools to develop disease resistant varieties** – *Fergus Meade* will explain how he has developed new DNA markers linked to regions of DNA conferring greater resistance to diseases, which he is using to accelerate the development of new disease resistant potato varieties
- **A new low cost DNA fingerprinting tool** – the ability to survey a plants DNA at a low cost is a requirement for many breeding applications. *Maria de la O Leyva Perez* will discuss the work she has been doing to develop such a system in potato
- **First Irish red clover variety** - a new red clover variety, FEARGA, has been bred by *Patrick Conaghan* at Oakpark. Red clover is an ideal break crop to improve soil structure and fertility
- **DNA assisted plant breeding** – using DNA based selection offers an opportunity to accelerate genetic gain in breeding and *Katie Hetherington* will explain how she is using these tools to increase forage yield of clover
- **Taking advantage of hybrid vigour** – *Abel Gari Teshome* will talk about his research into developing approaches to capture hybrid vigour during commercial seed production that can lead to higher yields in forage crops
- **Screening for flooding tolerance in winter barley** - increases in rainfall are causing significant losses in our winter crops. *Tomás Byrne* will discuss key traits that will allow future cultivars of barley to tolerate flooding

- **New tools for faba bean breeding** – *Vicky Tagkouli* from the University of Reading will discuss the establishment of a new recurrent selection breeding programme within VICCI targeting Irish growing conditions
- **Lab-On-a Chip to detect plant pathogens –** *Michelle Della Bartola* will explain how he is working on a project to develop new biosensors to detect two important pathogens, potato virus Y and *Rhynchosporium commune*
- **Speed-breeding for septoria resistance –** speed breeding was inspired by NASA experiments and *Adnan Riaz* will explain how he is using this technology in combination with rapid seedling assessments to identify and advance lines with greater disease resistance

Virtual Irish Centre for Crop Improvement

Six Crops

Four Challenges

Nutrient Use Efficiency

- Understand the genetics of NUE in breeding germplasm
- Develop high energy, low-N grain for monogastric feed
- Reduced N emissions and crop nutrition costs

Disease Resistance

- Need Irish-adapted varieties resistant to STB and FHB
- Identify germplasm, genes and markers associated with resistance
- Provide tools and information to breeding companies

Abiotic Stress Tolerance

- Low temperatures and flooding can limit productivity
- Investigate breeding germplasm using combined "omics" and field approach
- Develop tools for breeding stress tolerant varieties

Import Substitution

- Beans - potentially useful break crop and could help replace soy meal
- 200K tonnes of fresh/frozen potatoes imported annually
- Develop genomics driven breeding for these crops

Virtual Irish Centre for Crop Improvement
www.vicci.ie

Notes:

Virtual Irish Centre for Crop Improvement

What is VICCI?

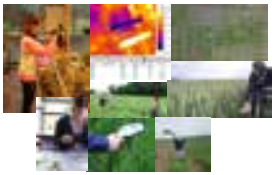
VICCI brings together crop and plant scientists from five institutions to address some of the most important challenges to Irish tillage and forage agriculture

Elite and adapted collections of six Irish agricultural crops from a variety of sources

Controlled environment and field-scale phenotyping of target traits for real world relevance

Multidisciplinary "-omics" approach to understand genetics and physiology of traits

Biotechnology-based tools (eg markers) and advanced germplasm to enable breeding of high performing Irish adapted crop varieties



Virtual Irish Centre for Crop Improvement
www.vicci.ie

Notes:

Tolerance to flooding in winter barley

Selecting Tolerant Cultivars

- Flooding creates low oxygen conditions for the crop
- Waterlogging caused an average of 68% grain yield reduction and and a 45% biomass reduction
- To breed flood tolerant crops we identified tolerant cultivars and traits that confer tolerance

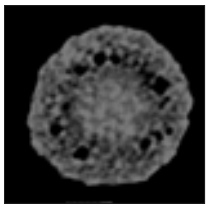
420 winter barley cultivars split into:

Tolerant cultivars

Sensitive cultivars

Adaptations to flooding

- We have identified root and shoot traits that contribute to tolerance to flooding
- We have identified several genes that allow for tolerance
- Aerenchyma (air pockets) have been identified in the roots of flood tolerant barley using CT-scanning
- These traits can be bred into new cultivars

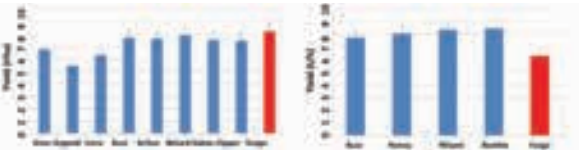


This work has been funded by DAFM RSF Project 14/S/819

Notes:

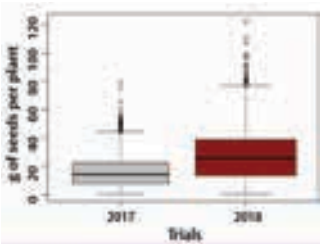
Recurrent Selection for high yielding Irish adapted faba beans

The Seasonal Type Paradox



Autumn-sown field trials show a ***spring*** variety – Fuego – outyielding ***winter*** varieties when disease pressure is low

Recurrent Selection 2016-19 and Preliminary Results



In-between cycles:

	2017	2018
No of harvested plants	1,454	1,581
Yield (kg)	23.8	44.5
Average seed number/plant	27.4	47.5
Average seed weight (g)/plant	16.4	28

Notes:

First Irish red clover variety

What is red clover?

AGRONOMY

- Legume
- Erect growth habit (20 to 80 cm tall)
- Perennial with 2 to 4 years lifespan
- Grown as monoculture or with ryegrass
- Primarily used for silage production
- Not persistent under continuous grazing

BENEFITS

Nitrogen fixation:

- 150 to 200 kg Nitrogen/ha/year
- Reduces dependence on inorganic N

Ideal break crop:

- Improves soil structure & fertility
- Green manure crop - mulch/plough in

High yields:

- 12 to 15 t DM/ha

High feeding value:

- High protein content
- High animal intakes
- Greater animal performance than grass silage

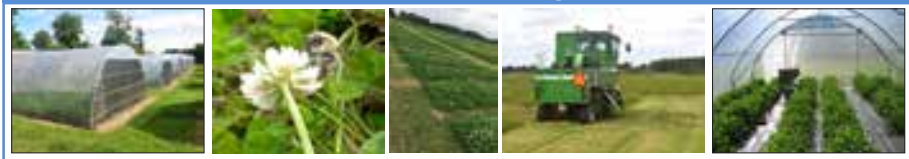
FEARGA: new red clover variety

- First Irish red clover variety, named **FEARGA**, bred at Teagasc Oakpark
- While no official red clover trials in Ireland, **FEARGA** has completed official UK trials
- **FEARGA** is highest yielding red clover in UK:
  - + 22% and 31% higher yield than Merviot in 2nd & 3rd harvest years
  - + 54% higher autumn ground cover than Merviot in 3rd harvest year
- **FEARGA** is the foremost red clover variety for Irish farmers

Notes:

DNA-assisted plant breeding

White Clover Breeding Process



What is DNA-assisted breeding?

DNA Analysis

Measure Traits

Develop statistical models

Offspring

DNA analysis

Predict breeding value from DNA information

How can DNA selection help white clover breeding?

It allows us to (i) reduce the length of a breeding cycle, and (ii) increase the number of plants we assess; meaning we can make greater gains sooner

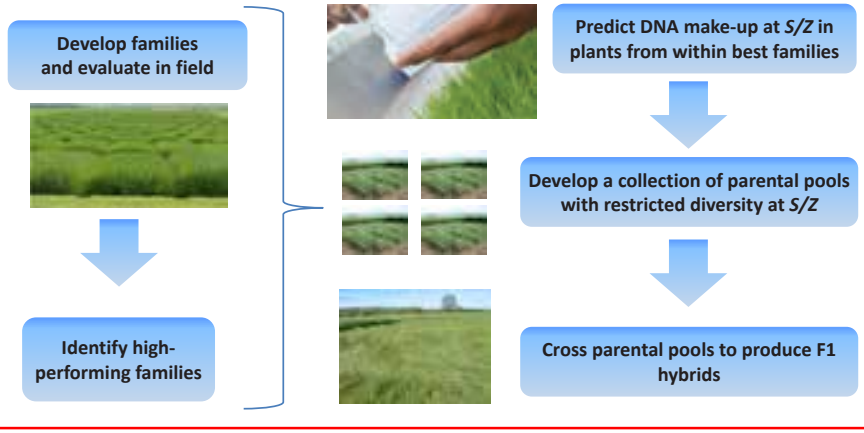
Notes:

Exploiting hybrid vigour

What is SI-based F1 Hybrid Breeding

- Crossing genetically distinct lines results in hybrid vigour
- Need a method to exploit hybrid vigour during commercial seed production
- DNA regions controlling Self-Incompatibility have been identified (S/Z)
- Develop parental pools with restricted diversity at these regions (using DNA markers predictive of composition at these regions)

Implementation



Marie Sklodowska-Curie Actions COFUND Grant Agreement no. CLNE/2017/364

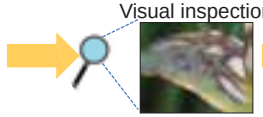
Notes:

A Lab-on-a Chip platform for detection of Plant Pathogens

Current methods for detection of plant diseases

Symptomatic plant

Visual inspection



- Unable to detect pre-symptomatic infections
- Difficult to associate non-specific symptoms with disease

Dispatch to laboratory

- Requires trained lab staff
- Expensive
- Slow turnaround time

Alternative methods to support rapid in-field detection?

- ✓ Field-based
- ✓ Cheap
- ✓ User friendly
- ✓ Rapid (minutes)

Developing a portable device, based on a nano-sensor coated with pathogen-specific antibodies. Goal is to be able to detect specific plant pathogens in symptomless tissues

Advantages of a Lab-on-a chip

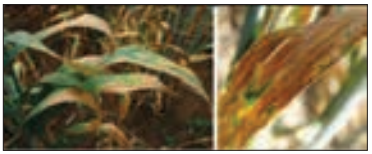
- Generated with antibodies specific for different crop diseases (e.g. Leaf Scald, Potato Virus Y)
- Detection performed directly by farmers, advisors and inspectors
- Provides precise decision support (e.g. fungicide applications, rogueing of infected plants)
- Integrated control of the disease, avoiding further spread of the pathogen with tailored inputs

SCOPE – a novel surveillance system for sensing crop diseases of economic importance (DAFM RSF Project 15/S/618)

Notes:

Speeding up for disease resistance

Traditional septoria assessment



~ 1 year

The 'Speed breeding' and septoria assessment

~ 4 months

Combining speed breeding with DNA-based selection for septoria resistance

Training population: DiverseMAGIC

Develop a prediction model

Select and cross best lines

Population improvement ~top 5-10%

New septoria resistant line

DNA- based selection

~1000 lines

Retrain the model

Field testing

. New septoria resistant line in 3 years compared to ~6 years

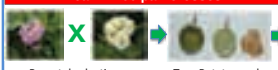
This work is funded by MARIE SKŁODOWSKA-CURIE ACTIONS Individual fellowships (IF)H2020-MSCA-IF-2017. ProjectGSAS (794040)

Notes:

DNA tools for potato breeding

Development of a new variety is a 12 year process

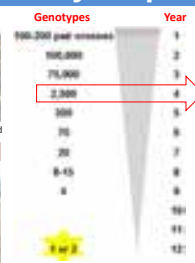
Year 1: 200 pair crosses



Parental selection — True Potato seed

Year 2: 100,000 Seedlings

Tuber from each seedling selected



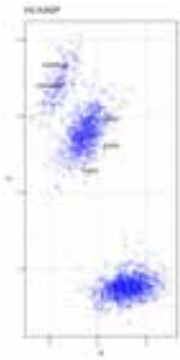
Marker Assisted Selection
for disease resistance

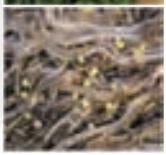
Years 3-12: Field evaluations

- Yearly increase in phenotyping effort as numbers are cut
- Over 50 traits assessed
- Advanced stage trials in the UK & Ireland and the Mediterranean

Using Marker Assisted Selection

- **Using DNA technology we can test for the presence of specific letters at a precise site in the genome**
- **These "molecular markers" are diagnostic for the presence of disease resistance genes in breeding lines**





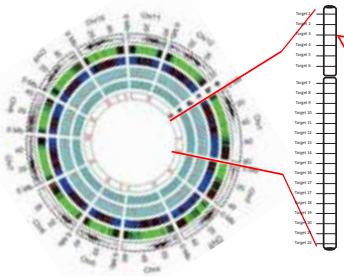
Notes:

PotatoMASH
DNA fingerprinting tool

Why this project

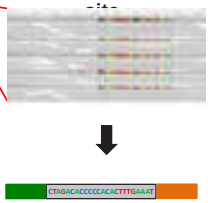
We want to scan DNA variation across the potato genome to dissect the genetic basis of important characteristics and use this information to breed better varieties

Scanning the potato DNA



1. Scan variation at 400 sites evenly spaced across the genome

2. Maximise variation at each site



3. Add barcodes for multiplexing

Thousands of plants in one run

1. PCR to amplify 400 sites from the DNA of each plant

2. Sequencing all plants in one tube

3. Use barcodes to track each sequence for each plant

4. Cost effective: as low as €4 per plant

Impact on Breeding

- Precision breeding using genomics
- Potentially reduce ten year breeding cycle
- A single genomics tool to select for all important characteristics

Fry colour

Disease Resistance

Yield

This action is supported by a Marie Skłodowska-Curie Individual Fellowship MSCA-IF-EF-ST 797162

Notes: