Project number: 6789
Funding source: EU - Marie S. Curie
Date: Dec 2018
Project dates: Oct 2015 – Nov 2017

GenSPI: Genomic Selection for Potato Improvement.

Key external stakeholders:
Potato Breeders, Growers, Processors.

Practical implications for stakeholders:
A large proportion of potatoes to serve the processing industry (especially the frozen chip trade) in Ireland are imported. One goal of the Teagasc potato breeding programme is to breed processing potatoes specifically adapted to Irish growing conditions, to encourage import replacement. In this project, we have developed genomic selection approaches that allow the efficient selection of key quality traits (fry colour, storage performance) during the breeding process. This will enhance the ability of the Teagasc potato breeding programme to develop Irish adapted processing varieties.

Main results:

- During the course of the project we demonstrated a working example of genomic selection for fry colour and resistance to low temperature sweetening in the Teagasc potato breeding programme,
- We demonstrated that good predictive value for these traits can be achieved with relatively few markers (hundreds rather than tens of thousands).
- The results form the basis of a possible low cost approach to routinely apply genomics-assisted selection in the Teagasc potato breeding programme.
- The phenotypic records collected in this project have directly contributed to parental selection and clone advancement in the Teagasc potato breeding programme.

Opportunity / Benefit:
The project was embedded directly within the potato breeding programme at Teagasc. Traditionally, potato breeders inter-cross plant varieties to produce up to 100 000 seedlings, and then eliminate poorly performing plant types over a period of 10 years. Varieties that exhibit good cooking quality characteristics can only be identified towards the end of this process, meaning that many potential varieties have already been eliminated from the breeding process. We envisage that genomic selection will enable the screening of thouands of individuals for key cooking quality traits at a very early stage in the breeding programme ensuring that only the most valuable material is advanced for extensive and expensive phenotyping. The research will result in an increased ability to breed potatoes suitable for processing but adapted for Irish growing conditions.

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1. Project background:

Ireland is a net importer of potatoes. In 2018, CSO figures indicated that 72K tonnes of potatoes were imported (approximately 44K tonnes from the UK) relative to 3K tonnes in exports. In addition to this, a further 120K tonnes of frozen potato products are imported on annual basis, mainly to serve the frozen chip market. This situation represents an opportunity for import replacement using indigenously produced potatoes. Current varieties suitable for these processing applications can be difficult to grow in Ireland due to environmental, soil and management constraints. In addition, the frozen chip trade requires year round supplies. Thus, robust varieties that are adapted to the Irish agi-environment, suitable for processing (especially chip production) and which possess good storage characteristics would help drive this import replacement opportunity. Developing such varieties is one goal of the Teagasc potato breeding programme.

Potatoes destined for chipping and crisping are normally stored at 8^0C, below this temperature reducing sugars accumulate, which leads to crisps being too dark in colour after frying and potential acrylamide build up. Conversely, when tubers are stored above 8^0C, sprouting occurs and this impacts product quality. This necessitates the use of sprout suppressant chemicals such as chlorpropham. The EU is moving to phase out the use of such chemicals, and it is therefore necessary to develop potatoes that can be stored below 8^0C without suffering from low temperature sweetening. Both fry colour and low temperature sweetening are under polygenic control and therefore challenging for traditional breeding programmes, particularly when they need to be combined with other traits such as yield and disease resistance. This is where new breeding methodologies such as genomic selection can assist traditional breeding programmes. Genomic selection is a form of marker assisted selection that simultaneously estimates all loci, haplotype, or marker effects across the entire genome to calculate breeding values. These breeding values can then be used to select individuals for advancement in the breeding cycle without direct phenotyping, which can be both time and resource intensive. Genomic selection for characteristics such as resistance to low temperature sweetening would radically enhance potato breeding, lead to the development of more suitable processing varieties for industry, and remove dependence on sprout suppressant chemicals.

2. Questions addressed by the project:

Is it possible to implement genomic selection for fry colour and resistance to low temperature sweetening in the Teagasc potato breeding programme?

3. The experimental studies:

A training population to evaluate the accuracy of genomic selection for fry colour and resistance to low temperature sweetening was established over the two years of this project. This was made up of potato entries at the year five stage of evaluation in the breeding programme, where the number of candidate varieties has gone from just under 100,000 lines to approximately 300 lines. The final training population consisted of 750 entries that were evaluated for fry colour 'off-the-field', and at various time points during storage at 4.5^0C and 8^0C (with sprout suppressant) . In total 9,440 tubers were sliced into crisps, deep fried, and analysed for fry colour using a HunterLab LabScan XE spectrophotometer. The training population was also genotyped using a genotyping-by-sequencing approach and a database of approximately 50,000 Single Nucleotide Polymorphisms (SNPs) was established.

4. Main results:

We evaluated various statistical algorithms and determined factors affecting predictive ability (e.g. training population size, marker density, and relationship between training and testing sets). Predictive ability was high (ranging from 0.61 to 0.72) when predicting fry colour at various time points during storage and reducing SNP number had limited impact on predictive ability. We also performed a genome-wide association study to identify individual SNPs associated with fry colour. This enabled the identification of subsets of as few as 100 SNPs that together were capable of predicting fry colour and resistance to low temperature sweetening with high accuracy (>0.6). Identified SNP markers had the same predictive ability as the entire marker set of

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50,000 markers and, significantly, had a greater predictive ability than a similar number of randomly selected markers, indicating that identifying specific markers linked to the genes responsible for the traits is beneficial in order to reduce the marker numbers required for prediction.

5. Opportunity/Benefit:

The identification of molecular markers predictive of fry colour and resistance to low temperature sweetening will be used to develop a cost effective genotyping platform to enable genomic-assisted selection for these traits. This genotyping platform will be deployed for indirect selection in early stages of the breeding programme when direct phenotyping of these traits is impractical. We expect that the work carried out in this action will lead to the release of varieties suitable for both Irish growers and the domestic processing industry, leading to opportunities for import replacement.

6. Dissemination:

Popular publications:

Byrne, SL, Griffin, D, and Milbourne, D (2016). GenSPI: Genomic selection for potato improvement. TResearch, Volume 11:Number 2. ISSN 1649-8917.

"POTATO DNA MARKERS COULD KEEP POTATOES FRESHER FOR LONGER". Article in RESEARCH EU RESULTS MAGAZINE, Issue no. 72, May 2018, p29, ISSN 1977-4028.

The project was featured in the publication "45 inspiring stories celebrating Ireland's 45 years of EU membership", produced by the European Commission Representation in Ireland.
https://ec.europa.eu/ireland/sites/ireland/files/brochuresinglepages.pdf

The work from this project was presented at the Plant and Animal Genome Conference, San Diego, USA, in 2016 and 2017. The titles were "*GenSPI: Improving the processing quality of potato varieties using genomic prediction*" and "*Using genomic variants to predict fry colour in potato*".

The work from this action was also presented at EAPR 2017 (European Association for Potato Research) with the title "*Using Genomic Variants to Predict Fry Colour in Potato*".

The project was promoted at the ESOF 2016 Euro Science Open Forum in Manchester.

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