INVESTIGATING THE ROLE OF ENGINEERED POTATOES DEVELOPED WITH DURABLE RESISTANCE TO POTATO LATE BLIGHT DISEASE

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The European potato sector is estimated to be worth ~€6bn per annum but potato late blight disease, caused by *Phytophthora infestans*, induces control costs and losses valued at ~€1bn per annum. For Ireland, in the period from 1983 to 2007 late blight disease reached epidemic proportions in all but 4 years. Since 2008, more aggressive strains of late blight have migrated across mainland Europe through the UK and into Ireland. So while Irish farmers have to apply fungicides up to 15 times a season to control late blight, during what are becoming more regular wet and humid summers, they have still struggled to control the disease as opportunities to spray become irregular. Combined with the imposition of increased EU legislation governing the use of pesticides, it is clear that the future sustainability of an economically viable potato sector is in doubt.

From the perspective of the late blight fungus, its success is due to its ever increasing ability to cause disease and its remarkable capacity to adapt. Significant research has focussed on identifying the genetic mechanisms the fungus uses to infect and destroy potato plants. Over the last 10-15 years, advances in biotechnology-based techniques have allowed researchers to investigate the control mechanisms of the fungus; for example how it perceives a potential host, how it evades the plants' resistance proteins and how the late blight organism adapts as the plant tries to defend itself.

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The need for durable genetic resistance to late blight disease

In parallel to investigating the fungus, the research community has also been focussed on identifying novel sources of robust, durable resistance to late blight disease. The most important word here is 'durable'; for if resistance is not resilient enough, the late blight fungus will quickly evolve to overcome the resistance. Technological advancements have made it now possible to identify and characterise multiple resistance genes from wild potato species. As a result, a novel series of genes with resistance to late blight disease has been identified and their number can be expected to increase as the pace of discovery and innovation continues to increase.

So how do these wild potato genes work? Firstly it is important to highlight the fact that unlike humans and animals who have legs to run away, plants have to fight standing still. Consequently, plants have evolved complex mechanisms to combat disease. Comparable to our body's ability to develop antibodies to fight infection, plants have a series of defence proteins, the blueprint of which is coded by the resistance genes. So the more resistance genes available to the plant, the more resistance proteins the plant can produce to fight infection. In addition, certain resistance genes have the capacity to expand their ability to produce resistance proteins. Hence the plant can adapt quickly to produce in effect an updated model of the resistance protein, in order to fight a new strain of a particular disease, for example.

Not surprisingly, diseases such as late blight have evolved at a similar rate, to the point that the interaction between potato and late blight disease is equivalent to a de facto 'arms race'. As one develops a mechanism (or protein) to overcome its opponent, the pressure is on the other to counter or else face defeat. So, in response to the resistance proteins of potato, late blight disease has to develop new proteins that the target plant has not yet experienced. This point is the most critical; for unlike in Ireland where potato and late blight have only known each other since the 1800s, the potato genes taken from wild, weedy potato species that inhabit Central and South America have experienced late blight for hundreds of millions of years and as a result are not averse to dealing with this pest. That is why researchers have focussed on several wild potato species, for they display durable resistance to late blight disease. It is this level of robustness that has incentivised researchers to transfer these genes into commercially important potato varieties.

Mechanisms of gene transfer

This process of transfer can be done through conventional breeding methods but two issues arise: time and specificity. Time, because it takes a minimum of 10 years to breed a new potato variety and specificity, because by relying on traditional breeding you not only achieve the transfer of your gene of interest but you also end up transferring 1000s of unwanted wild potato genes into your target variety, typically resulting in a negative agronomic impact on the resulting progeny.

Employing cisgenics (lab-based transfer of a gene(s) between two related species), it is now possible to transfer a single gene from a wild potato into a conventional potato variety, achieving a new potato line in a matter of weeks; hence potentially delivering an upgraded version of an existing variety that previously had negligible blight resistance. In essence cisgenics is a method to accelerate breeding and it was a cisgenic potato line that we have evaluated in Ireland over the last 4 years: both from an agronomic and environmental perspective.

Late blight in the EU AMIGA project

As part of the EU funded 'AMIGA' project we have assessed and monitored the impact of a cisgenic potato, genetically engineered with late blight resistance. Based on field evaluations at our site in Carlow, Ireland, our work was focussed on addressing 4 primary objectives:

- Quantify the agronomic performance of the generated resistance variety and determine the corresponding response of late blight strains to the novel material.
- Assess the impact of cultivation on soil microbial diversity.
- Estimate the compatibility of managing a cisgenic variety with IPM principles.
- Initiate an objective public discussion on the challenges facing future potato production and the costs/benefits of potential solutions.

After completing three years of field experimentation (2013-2015), the AMIGA project [1] is currently in the stage of data analysis and dissemination. To date we have published our findings on the cultivation of cisgenically engineered blight resistant potato on soil diversity [2]. In short, this paper concluded that the engineered potato variety had no negative impact on the diversity or community structure of soil nematodes, which are typically labelled as a barometer of a soil's health. Follow on manuscripts on bacterial and fungal diversity, as well as the agronomic performance of the material relative to IPM principles are expected in 2017. Meanwhile a separate study of AMIGA, completed by our colleagues at the JHI, examined the efficacy of extrapolating the results of our controlled field studies across landscapes to quantify the impact late blight resistant potatoes would have on environmental quality and production practises.

Public debate and dissemination

From a social science perspective, we embarked on a proactive strategy of dissemination with all stakeholders in the GM debate, which saw us participate in a total of 86 dissemination events over the 4 years of the study. From the outset, we made a commitment to the public that project scientists would be accessible on request, be it for public debates, media interviews, social media commentary, focus groups or general queries received by Teagasc from concerned and interested parties. In addition, the 'what' and 'why' of the project would be coherently delivered while scientific principles and theory would be explained in a non-scientific manner. At all times, the focus of our initiative was to ensure that all discussions we participated in were framed by objectivity and that ideologies and opinions were addressed with scientific fact.

As we conclude the scientific goals of the AMIGA project, its output is currently undergoing independent peer review to ensure scientific validity and standards are achieved. Through international collaboration, the project has made a clear contribution to advancing our understanding of how cisgenically engineered late blight resistant potato can contribute to reducing the increasing impact of the economically damaging disease that is potato late blight.

References

[1] AMIGA "Assessing and Monitoring the Impacts of Genetically modified plants on Agro-ecosystems" is a European project funded by the European Commission under the Framework Programme 7 (FP7): http://www.amigaproject.eu/

[2] Ortiz, V., Phelan, S., Mullins, E. (2016) A temporal assessment of nematode community structure and diversity in the rhizosphere of cisgenic *Phytophthora infestans*-resistant potatoes. BMC Ecology, 16:55 DOI: 10.1186/s12898-016-0109-5