Breeding for resistance

INTERNATIONAL YEAR OF PLANT HEALTH 2020

TEAGASC researchers are using lessons from the past to guide the future of breeding potatoes for late blight resistance.

The success of the potato in Ireland prior to the famine was due to its exceptionally high yield, low input requirement, short cropping season and high nutritional value. Potato favours a cool climate with adequate rainfall and is particularly well suited to Irish conditions. By the early 19th century, these characteristics had made it a lynchpin of the diet of a largely agrarian Irish population. In 1845, when late blight arrived in Ireland, the main variety, Lumper, which was selected for its extremely high yield, was especially susceptible, which led to complete destruction of the crop.

First organised breeding

Potato breeding is performed by sowing true seed from potato berries (derived from crosses between pairs of existing varieties) and selection of the best performing seedlings. Records show that informal selection or breeding of potato varieties was taking place around the time of the famine, as true seed was being produced and traded. These informal breeding efforts were conducted by individual farmers, botanists and gardeners on the basis of yield and taste. When the true cause of potato blight was discovered it kick-started the area of formalised potato breeding, particularly for late blight resistance. In Ireland, the first organised breeding effort was carried out in 1881 by the director of the Albert Institution, Thomas Carroll, who distributed true seed of potato varieties to national schools around the country for selection in school gardens. Although many varieties were produced from this programme, it did not yield any highly successful varieties; the national crop was dominated by the Scottish variety Champion, which exhibited some blight resistance, until Kerr's Pink became dominant in the early 20th century. The improved resistance of these varieties, although incomplete, coupled with use of early fungicides such as the Bordeaux mixture (based on copper sulphate), allowed continued potato cultivation in Europe in the face of continuing blight pressure. International breeding efforts in the 1950s and 1960s focused on introgression of major resistance (R) genes to cultivated potato from the wild Mexican potato species *Solanum demissum*. These R genes conferred near complete resistance; however, the resulting resistant varieties soon became susceptible, indicating poor durability and the ability of *Phytophthora infestans* to evolve and 'break' the resistance they confer. Further breeding efforts, both Irish and international, focused on 'field resistance', which was believed to be more durable because it was partial and did not rely on R genes, but rather on a combination of different physiological factors controlled by many genes.

Teagasc breeding programme

The potato breeding programme in Teagasc was set up in 1962 to breed varieties primarily for the domestic market and blight resistance was a major focus. During the 1970s Teagasc formed a partnership with IPM Potato Group to breed varieties for both export and domestic markets. Varieties produced by this programme, including Cara, Setanta, Orla, Galactica, Banba, Druid and Kikko, exhibited good levels of partial resistance to the pathogen, and Orla and Setanta are widely grown for organic production, at least in part because of this resistance. In the last 20 years a revolution in our understanding of plant–pathogen interactions has taken place, and the differences between field resistance and major gene resistance have become blurred. It is apparent that some varieties possess multiple R genes, the

Late blight-resistant seedling surrounded by susceptible seedlings.

Late blight resistance screening trial demonstrating effect of resistant genes from wild species in potato.

combination of which give both strength and durability in terms of blight resistance (a good example is the variety Sarpo Mira). At the same time, screening wild relatives of cultivated potato has identified numerous new R genes, from species other than *S. demissum*, which exhibit very strong levels of resistance, and seem to break down more slowly in the face of a constantly evolving pathogen. One important lesson has been that it is important to maximise the difficulty experienced by the blight pathogen in evolving to overcome R genes bred into varieties. One approach is to 'stack' multiple R genes into varieties. This contributes to the durability of resistance, as the blight pathogen has to go through multiple mutation and selection events to overcome multiple R genes. Another concept is to use R genes in the context of a wider integrated pest management (IPM) strategy, where other control methods, such as early cropping, decision-support systems and judicious use of fungicides, reduce the adaptive ability of the blight pathogen and help to protect naturally resistant varieties while reducing cost and environmental burdens.

Marker-assisted selection

In conventional breeding, the cycle of development for a single variety after its two parents are crossed is over a decade, and this limits the ability to stack multiple R genes quickly; it can take several decades to achieve multi-R-gene stacks. Genetically modified (GM) approaches for stacking have been demonstrated to be highly effective, and would greatly speed up the development of durably resistant varieties, but the technology remains unpopular in Europe, and no significant GM potato varieties have been released in the EU. In response to these time constraints, conventional breeding programmes such as the Teagasc/IPM Potato Group programme are developing technologies to augment and speed up the development of resistant varieties. At Teagasc, we are engaged in identifying novel R genes and developing genetic fingerprinting assays for these genes, to be used in a strategy called marker-assisted selection. This has contributed to the development of varieties such as Java, which combines resistance to late blight, potato virus Y, potato cyst nematode, and wart disease. In collaboration with international partners, potato breeders and geneticists at Oak Park Research Centre are also exploring novel 'rapid-cycle' breeding approaches such as diploid hybrid breeding and fixation-restitution breeding (diffugat.eu), which have the potential to cut variety development time in half.

Potato is the most important non-cereal food crop in the world, important in both the developed and developing world due to its productivity, nutritional profile and potential to build profitable value chains. While consumption is dropping in the western world, potato is expanding in the global context, and late blight remains a major constraint on production. Lessons that began with the famine continue to guide potato breeders and scientists in Ireland and across the world in combatting this challenging disease.

Acknowledgement

DIFFUGAT is funded under the ERA-NET Cofund SusCrop (Grant N°771134), being part of the Joint Programming Initiative on Agriculture, Food Security and Climate Change (FACCE-JPI). Teagasc participation is supported by the Department of Agriculture, Food and the Marine. The Potato Breeding Programme in Teagasc is a collaboration with IPM Potato Group Ltd.

Authors

Denis Griffin
Research Officer, Teagasc, Crops Research Centre, Oak Park, Carlow
Correspondence: denis.griffin@teagasc.ie

Dan Milbourne
Research Officer, Teagasc, Crops Research Centre, Oak Park, Carlow