# Breeding and genetics

George R. Mackay

*Genetic variation or biodiversity within crop species is an essential pre-requisite for continued production of new improved cultivars. This is particularly so if those new cultivars are to be more resistant to pests and pathogens and less reliant on routine prophylactic agrochemicals, to maintain their yield and quality. The European form of the potato, Solanum tuberosum ssp. tuberosum, represents perhaps a classic example of a crop species which lacks genetic variation and, consequently, requires substantial inputs of agrochemicals to maintain its productivity. The sustainability of this approach is questionable for a crop which ranks fourth in world importance after wheat, maize and rice, in terms of human food production.*

The potato is a relatively recent introduction into Europe, having been introduced during the Spanish conquest of South America about 500 years ago. These early introductions are believed to have been of the subspecies *andigena*, still cultivated in its native Peru. Adapted to the short days of equatorial regions, it took approximately 200 years for *andigena* to evolve into the long day adapted *tuberosum* form which predominates world-wide today. Limited introductions of *andigena*, and the loss of genetic variation that will have taken place during its evolution in Europe, meant that *tuberosum* offered no resistance when late blight was introduced from Mexico to Europe in the mid-19$^{th}$ century, and caused the catastrophe that halved the population of Ireland. More recently, as potato cyst nematode populations increased due to shortened rotations in the mid-part of this century, it was quickly found that no European forms of potato possessed resistance to this serious pest.

Recognising *tuberosum's* narrow genetic base, breeders have successfully introgressed genetic resistance from several of the many related wild species and primitive forms that exist in Central and South America. Perhaps the most striking example was the rapid introgression of the $H_1$ gene, conferring resistance to the golden cyst nematode (PCN) pathotype $RO_1$, from ssp. *andigena* CPC1673, into *tuberosum* and now available in most modern cultivars. Unfortunately, introgression of more complex genetic resistance to

the white cyst nematode, from more distantly related wild species such as *Solanum vernei*, has taken much longer and is only partially effective.

SCRI researchers are fortunate to have immediate access to the Commonwealth Potato Collection (CPC) of approximately 1,400 accessions representing more than 80 species of the tuber-forming members of the genus *Solanum*. The conservation and maintenance of such *ex situ* gene banks is particularly important when access to the wealth of genetic diversity in Central and South America is time consuming and costly due to the need to passage any *Solanum* material from the Americas through quarantine. However, conservation and maintenance is of little value if the germplasm is not properly characterised and utilised. At SCRI, though good levels of resistance to late blight and potato cyst nematodes are being achieved in recently released cultivars, and combined effectively in the multi-trait breeding experiment, we are conscious that our sources of resistance are limited to rather few species. It is strategically very important that additional, hopefully novel, sources of resistance are found and introgressed into *tuberosum*, lest the currently available sources are defeated by new strains of pest or pathogen.

Recently obtained external funding from the EU and an SOAEFD Flexible Fund project have provided the opportunity to expand the search for new sources of resistance to both late blight and PCN in the CPC. To date, sources of resistance to late blight have been identified in 57 accessions belonging to species from the seven taxonomic series within the tuber-bearing part of the genus *Solanum*. Not surprisingly, many of these are from Mexico, centre of origin of late blight itself, but several are from Bolivia and Argentina.

Potentially, *Solanum papita*, a tetraploid Mexican wild species, seems to be a very useful source and has been successfully hybridised using mentor pollen and embryo rescue with a tuberosum cultivar. It was intended that, with molecular marker aided selection and rapid screening for resistance of the backcrosses to tuberosum, this complex form of resistance could be introgressed rapidly into agronomically-adapted tuberosum. However, the resistance tests on the $F_1$ and backcross populations produced so far are proving difficult to interpret. Further crosses between resistant and susceptible accessions of *papita* itself are planned, so that the genetics of this potentially novel form of resistance can be interpreted. In the meantime, however, a diploid population of the species *S. verocossum* produced from crosses between susceptible and resistant accessions, is proving most useful. Being diploid and self-compatible makes this species ideal for genetical research and several molecular markers linked to QTL for late blight resistance have already been identified. This material will also prove ideal to investigate the feasibility and efficacy of molecular marker-aided selection at the diploid level. Similarly, at the tetraploid level, molecular markers linked to a major QTL for PCN resistance derived from *S. vernei*, have been located on linkage group IV. This QTL is only present in cultivars containing *vernei*-derived resistance and will also be extremely useful in establishing the effectiveness of marker-aided selection for *vernei* resistance at the tetraploid level.

Potentially useful, high levels of resistance to the bacterial *Erwinias*, which cause soft rot in tuber have been identified in the cultivated diploid group *phureja*. As these are clones from the unique SCRI long day adapted population of *phureja*, introgression into *tuberosum* should be relatively easy and the diploid status of *phureja* also facilitates studies into the genetics of resistance. Some clones from crosses between two soft rot resistant parents are also showing good levels of resistance to blackleg.

In addition to proving a valuable source of resistance and a strategically important resource for fundamental research into genetics, SCRI long day phurejas may have a direct commercial potential as flavoursome, high value novelty potatoes. In 1998, two *phureja* clones were submitted as potential cultivars for National List Trials on behalf of two private sector organisations, who have been funding the routine testing, trialling and selection through MRS Ltd.

Classical hybridisation and backcrossing to introgress genetic variation from wild species of *Solanum* into *tuberosum* can be time-consuming or not possible, particularly if the species have a different endosperm balance number (EBN) to *tuberosum*. Differing levels of ploidy and other factors can also result in sterility

problems, which hinder or prevent progress. Bridging crosses, embryo rescue and artificial manipulation of ploidy (with colchicine) can overcome some of these difficulties. The use of marker-aided selection may speed up the process by reducing the number of back-cross generations, but is yet to be proven. An alternative is to circumvent all the problems of sexual hybridisation by bypassing it altogether. We have been very successful at developing somatic fusion as an asexual means of hybridising wild species with *tuberosum*. In 1998, 283 protoplast-derived clones were grown in small, 4-plant plots at Blythbank. Fifteen per cent were selected for retrialling in 1999 on the basis of their agronomic potential, compared with control cultivars. These selected clones included somatic hybrids between two cultivars and three wild species, the latter identified in earlier research as possessing resistance to late blight or PCN. Further work is needed, but the potential for genetic introgression via somatic fusion has clearly been demonstrated.

Molecular techniques, alluded to earlier as a means of increasing the efficiency of breeding using marker-aided selection, also provide extremely powerful tools for analysis and objective quantification of species relationships and biodiversity.

In a recent SCRI survey of 178 potato cultivars on the UK National List, using a combination of nuclear and chloroplast SSRs (microsatellites), a paucity of chloroplast genetic variation was highlighted, which was not seen at the nuclear level. Eighty-five percent (151) of these cultivars had exactly the same 'T type' cytoplasm. Our observations suggest that, unless diverse chloroplast types are actively chosen as parents in potato breeding schemes, the cultivated potato in the UK, perhaps Europe, even globally, may ultimately be represented by a single chloroplast haplotype. This could expose this extremely important food crop to the sort of devastating epidemic that occurred amongst the corn (maize) crop in the USA in 1970, when a strain of southern corn leaf blight attacked 70 percent of the maize in the USA, which had a single source of cytoplasm susceptible to the pathogen. An encouraging observation has been that the parents of the SCRI multitrait breeding scheme possess eight distinct cpSSR haplotypes compared to the two to three of modern and old cultivars respectively, a potentially serendipitous bonus that was not envisaged at the start of this scheme.

In addition to the research on potatoes, the Crop Genetics Department continues to maintain an interest in other crops. The commercially-funded swede breeding programme, based on single seed descent from F1 hybrids between selected SCRI parents, will reach the stage where the lines are sufficiently inbred for field trialling in 1999. Projects funded by the European Union and another by the Department for International Development are successfully achieving the efficient transformation of grain legumes and chickpea, and are described elsewhere in this year's report. The first summer's work on a MAFF-funded project, designed to quantify pollen and hence gene flow in oilseed rape, has produced some surprising – perhaps controversial – findings. Airborne pollen deposition was shown to decline steeply with distance to a low 'background' level, but a consistent fertilisation of about 5 percent of flowers on male sterile 'trap' plants was maintained up to 4 km from the nearest known fields of commercial oilseed rape crops. Though this may be an overestimate of what may occur with normal male fertile plants, DNA fingerprinting was able to confirm the source of pollen reaching the male sterile plants and that this was often a mixture of pollen from different source crops.

The commercially-funded potato breeding programmes continue to achieve, or exceed, their objectives. In addition to the two *phureja* clones mentioned above, three other *tuberosum* clones were also submitted to National List Trials, two being potential processing varieties from the Targeted Accelerated Breeding programme (Ann. Rep. 1996/97, 40-43). The new cultivars Amour (an export variety aimed at the Mediterranean region) and Blush (an attractive first early) were added to the National List and will be being commercialised by our private company partners.