Legislation for safety The United Kingdom was one of the first countries to introduce controls on modern biotechnology. These controls were introduced in 1978, not in response to any identified health or environmental problems, but rather because of the lack of familiarity with the behaviour of GMOs and the need to ensure safety. The current legislation governing the release and marketing of GMOs aims to prevent or minimise damage to the environment. Part IV of the Environment Protection Act 1990 and the regulations made under it, are in line with recommendations made by the Royal Commission on Environmental Pollution and implement the EC Directive on Deliberate Releases into the Environment of GMOs. No GMO can be released or marketed without prior consent of the Secretary of State, acting jointly with the Minister of Agriculture, Fisheries and Food. In every case, the Secretary of State seeks expert advice from the independent Advisory Committee on Releases to the Environment, a committee composed of public and private sector experts, including representatives from environmental groups. UK regulations require a full assessment of the environmental impact and risk of any intended release, and every consent holder has to monitor the environmental effects of a release. Before GMOs can be marketed, they must also be approved at European Community level with all member states able to raise objections. In January 1997, the European parliament approved the text of the European Novel Food Regulation and this became law at the end of April. This definition of Novel Food includes food or food ingredients containing or consisting of GMOs or that have been produced from but not containing GMOs. The regulations are aimed at ensuring that food covered by this Regulation does not present a danger to the consumer, does not mislead the consumer, and does not nutritionally disadvantage the consumer.

In summary Genetically modified plants have great long-term potential and we are only in the early stages of utilising this. For public acceptance in the short term, there is a need to clearly explain the benefits of gene transfer technology. These benefits must not only be in terms of the profitability of firms and farmers; consumers must be aware of the benefits to them in terms of cost, food quality and the environment. It is clear that agriculture has to be efficient, particularly in terms of limited resources and has to be as free from negative effects on the environment as is possible. It must also meet the consumer demands who require fresh produce regardless of season. With this understood, the benefits of genetically modified foodstuff should be clear.

In conclusion therefore, genetic manipulation is not something we should fear but is a process which should be harnessed in a positive manner for not just our good, but for the good of our environment.

Rubus breeding and genetic research

R.E. Harrison, R.J. McNicol & S. Jennings

Historically, raspberry production in Scotland has been for processing through preservation as pulp for jam manufacture, canning or freezing. Although fresh fruit production in Scotland is slowly increasing, it remains a small part of the industry (c. 6 % in 1995). Current Scottish raspberry production remains focused on processing, although the market has changed dramatically. Whereas most fruit was processed as pulp in decades past, only 38% of the crop went to pulp in 1995 and 20% in 1996. The shift away from pulp is due to economics. The best prices for processed fruit now come from Individually Quick Frozen (IQF) fruit and other novel processed products.

Other changes in the economics of raspberry production in Scotland have altered the industry. As production costs increase, it has become difficult for all growers to remain competitive and this has lead to a steady decline in the Scottish raspberry area. Some fifteen years ago, raspberries were grown on around 2800 ha which produced about 13,000 to 14,000 tonnes of fruit. By 1990, this had dropped to 2300 ha producing 10,000 tonnes and currently about 1,300 ha can produce anywhere from 4,000 - 8,000 tonnes of fruit. The direct causes for this drop in production are numerous. A ban on the chemical cane-suppressant, Dinoseb, in 1987 caused dramatic reductions in the yield of the most commonly grown cultivar, Glen Clova, due to the increased incidence of cane midge and its associated midge blight[1].

The appearance of raspberry root rot in the mid-1980's has also affected much of the crop (estimated by SOAEFD at c. 30%). The fungicide, Recoil (mancozeb + oxadixyl), has been effective at keeping the fungus under control. However, many hectares were lost from the initial outbreak and many of these have not returned to raspberry production despite the successful chemical control. Healthy planting stocks and resistance breeding, in conjunction with improved management practices, will be the only long-term method of avoiding damage from raspberry root rot.

Fierce competition from eastern European pulp, selling at highly competitive prices, has kept prices low for Scottish growers. This competition is likely to increase before it diminishes, as France and Spain become established in the European raspberry market and Chilean products dominate the market during the winter. High quality fruit is likely to become the separating factor between the inexpensive eastern European fruit and UK fruit, and will allow the UK to continue production in this highly competitive market.

Possibly the most dramatic impact on the Scottish industry has been the gradual loss of a dependable work force. The Scottish crop was traditionally picked by hand, using a pool of around 40,000 people from neighbouring cities during the summer months. Various changes in welfare and tax regulations, and simply a breaking down of the summer tradition of picking raspberries, have each added to the loss of this labour force[2]. Growers have responded to this problem by adapting current cultivars and management practices to machine harvesting (Fig. 1). There are currently some 50 machine harvesters operating in the UK. As part of this change, the selection of cultivars specifically intended for machine harvesting is an important goal of the breeding programme. Recent cultivars from SCRI, including Glen Ample and Glen Rosa, and several older cultivars, Glen Moy and Glen Prosen, are useful cultivars for machine harvesting. However, there is still an obvious need to improve cultivars for adaptation to machine harvesting. In fact, each of these challenges for the raspberry industry identifies new opportunities for the breeding programme to develop cultivars with improved fruit texture, colour and flavours specifically selected for these new industry requirements.

Figure 1 Machine harvesting at a grower's site.

To overcome some of the difficulties facing the raspberry industry, growers formed a marketing co-operative called the Scottish Soft Fruit Growers Ltd, which gained funding in part through joint UK / EU grants. The grants are to assist in many aspects of the restructuring of the raspberry industry, including capital assistance for planting and purchasing machine harvesting equipment, development of a technical advisory service as well as the funding of the raspberry breeding programme at SCRI.

Raspberries have been bred in Invergowrie, Scotland since the 1950s (Fig. 2). First by the Scottish Horticultural Research Institute (SHRI) and then by SCRI after the amalgamation of SHRI and the Scottish Plant Breeding Station. These 'finished-cultivar'programmes were originally run with government funding, but since 1991 the funding of the programme has been provided by Scottish Enterprise Tayside, the Scottish Soft Fruit Growers Ltd and the Horticultural Development Council - the latter two organisations through a UK / EU grant for the redevelopment of the Scottish raspberry industry. SCRI researchers maintain close contact with the industry

Figure 2 Early days of raspberry breeding in Scotland c.1954.

through the Scottish Soft Fruit Growers Ltd and the breeders strive to develop cultivars that meet the rapidly changing requirements of the UK raspberry industry.

Rubus breeding at SCRI is currently focused on raspberries and blackberries. Some work also continues on blackberry-raspberry hybrids, as well as novel fruits like the purple and yellow / amber raspberries. The objectives of the programme are two-fold: first to enhance the germplasm that is available to commercially oriented breeding programmes; and second to breed commercially acceptable raspberry cultivars through improvements in fruit quality, yield, plant habit, machine harvest ability and resistance to pests and diseases. The programme is essentially a recurrent

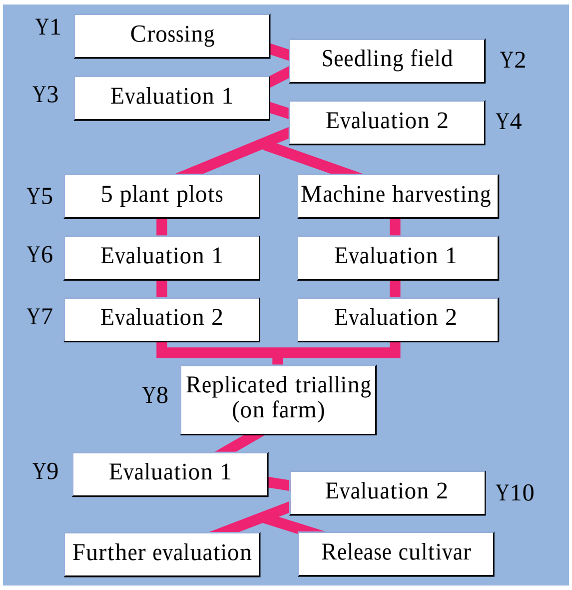

Figure 3 A diagramatic representation of the raspberry breeding programme with each level of the chart representing 1 year in the programme cycle (Y1 - Y10).

selection programme (Fig. 3). Each year selections are made and these selections form the basis of the next generation of crossing. It is not, however, a closed system. As new variability for certain traits is needed, elite cultivars and selections from outside the selection programme are included as parents.

Figure 4 Parents are lifted from the field in the autumn and forced into flower in a glasshouse the following winter. Specific parents with complementary characterisitics are cross pollinated by hand in the glasshouse.

Each year, approximately 30 selections and cultivars are chosen as parents and approximately 100 crosses are made. Dormant parent plants are brought into a glasshouse in mid-December and forced into flower by mid-January. Nearly all of the crossing is now done in glasshouses during the winter (Fig. 4) with field crosses only necessary on rare occassions. Seeds are extracted from fully-ripe fruit in April, acid-treated and then stratified at 4^{o}C for 4 to 6 weeks. We aim to produce between 100 and 200 seedlings from each cross. These are initially grown in a glasshouse for preliminary screening for the absence of spines and for aphid resistance. Spined genotypes are removed from segregating families, as nearly all SCRI breeding stocks now carry the recessive gene (*ss*) for spinelessness. Over 90% of the families are also segregating for the A_{10} gene for resistance to all known biotypes of the large raspberry aphid. This aphid is a vector of several important viral diseases, and resistance has played an important part in increasing the longevity of modern raspberry plantations.

The programme begins with about 12,000 seedlings. Elimination of spined and aphid-susceptible genotypes leaves approximately 5000 seedlings for field planting in late October. The plantation requires one

Figure 5 Promising raspberry selections are evaluated for machine harvesting using a Korvan raspberry harvester.

Figure 6 Machine harvested plots are assessed for yield and the quality of fruit harvested. The sample in the upper-left and upper-central positions are promising machine harvesting selections.

year of growth for plants to establish and to produce suitable primocanes on which fruit is borne in the second year. Seedlings are evaluated for numerous fruit characters during the first two fruiting seasons. Initial evaluations are on fruit size, shape, colour, firmness, flavour, shelf-life, and ease of fruit removal as an indication of suitability for machine harvesting. Some secondary assessments for fruiting-lateral characteristics are made, but more detailed evaluations of vigour, cane characteristics, and yield are not made until these selections are propagated into small plots. Each selected seedling is also initiated in tissue culture to establish a stock-plant free from root diseases. Approximately 1 - 2 % of the seedlings are selected at this stage.

Once a potential parent or new cultivar has been identified in the seedling field, it is propagated from root cuttings for further evaluation in duplicate five-plant plots. These plots are fruited for 2 - 4 years and detailed evaluations are made, including yield. Promising machine harvesting selections, based on ease of picking (removal of the plug), are also propagated into 20 m plots for machine harvest evaluation. Machine harvesting trials consist of single plots of each selection and several control plots. These plots are harvested using a Korvan machine harvester (Fig. 5). Total yield is measured and visual assessments made on these fruit (Fig. 6). Additionally, a small sample is collected from each harvest and evaluated further to quantify the proportions of fruit in various quality categories (IQF, under-ripe, over-ripe, ripe with plug, diseased and broken laterals).

Within 3 years, the best machine harvesting genotypes are selected from the trial. The tissue-culture-propagated stock-plant of each selection is then virus tested and multiplied in tissue culture to provide plants for on-farm assessment at many sites. At this time, a propagation bed is also initiated. This gives SSFG members fast access to reasonable quantities of planting stock once the best selection(s) is identified.

Although importance is placed on developing cultivars quickly, there is a balance between rapid evaluation

Species	Origin	Useful characters
R. occidentalis (Black raspberry)	*North America*	Fruit firmness; resistance to aphid and cane diseases
R. pileatus	*Asia*	Firm cohesive fruit; resistance to cane diseases and root rot
R. coreanus	*Asia*	Firm cohesive fruit; resistance to cane diseases, root rot, raspberry beetle and powdery mildew
R. spectabilis (Salmonberry)	*North America*	Earliness in summer- and autumn- fruiting raspberries; resistance to root rot.
R. cockburnianus	*Asia*	High fruit number per fruiting lateral (high yield potential); resistance to cane disease
R. crataegifolius	*Asia*	Resistance to raspberry beetle, cane midge and cane botrytis
R. phoenicolasius (Japanese wineberry)	*Asia*	Resistance to raspberry beetle

Table 1 A list of wild species, their origins, and useful characters for raspberry improvement in the *Rubus* breeding programme.

and stability of performance. Yield can fluctuate from year to year for a variety of reasons, such as establishment, climate, and damage from machine harvesting. Each of these factors can affect vigour of primocane production and reduce yield in the following season. Therefore, we believe that it is important to observe selections for a minimum of two fruiting seasons, particularly in the machine harvesting trials, before a proper assessment of the consistency of performance can be obtained. Historically, it has taken from 12 to 15 years to produce a finished cultivar following an initial hybridisation. Early identification of valuable selections, early virus testing and tissue culture each help to reduce this development time by 2 to 3 years.

Most of the characteristics required for raspberry improvement are available in raspberry cultivars introduced by SCRI and from breeding programmes in other parts of the world. Exotic species that are closely related to the raspberry are also needed as a source of novel variability (Table 1).

Germplasm enhancement, the adaptation and transfer of exotic germplasm from wild species into elite breeding lines, is an important aspect of any progressive breeding programme. Although the major emphasis within the SCRI breeding programme remains the development of commercially acceptable cultivars, research into novel genetic resources continues. In cooperation with Dr Chad Finn of the United States Department of Agriculture (USDA) - Oregon and the National Clonal Germplasm Repository (NCGR) in Corvallis, Oregon, we are beginning to evaluate seedlings from numerous wild species of *Rubus* for root rot resistance, aphid resistance, RBDV resistance, novel fruit colour, and raspberry beetle resistance, as well as, general horticultural characters. Through the NCGR, we have access to hundreds of wild *Rubus* accessions. Dr Finn has initiated a screening programme for adaptation to a temperate climate and has reduced the number of potentially useful accessions that include *R. sachalienensis*, *R. niveus*, and *R. sumatranus* and a red-fruited form of *R. coreanus*. Preliminary research will assess small samples from each of these species for useful traits as well as cross-fertility with *R. idaeus*. Seedlings from fertile crosses will be examined further to study the inheritance of these useful traits in the interspecific hybrids.

Adaptation of exotic germplasm is vital to the rapid transfer of novel genes into cultivated species. However, locally-adapted wild *R. idaeus* material from Britain can also be a source of important traits. In cooperation with Geoff Squire (CEP), Julie Graham (SFPC), and Bruce Marshall (CEP), local *R. idaeus* populations have been evaluated for molecular and morphological variation. These plants are also being assessed for horticultural characteristics to identify useful traits for the breeding programme.

Root rot has been studied at SCRI since the mid-1980s. In the early 1990s, 12 genotypes were identified as having root rot resistance from glasshouse screening and then from an additional field test in an infected site. These resistant parents were backcrossed to elite SCRI material and seedlings from these crosses were planted into an infected site for field evaluation. It will take several years for the fungus population to build up to effective levels. However, surplus plants from some families were evaluated for resistance in the glasshouse. All families showed some levels of resistance (Fig. 7). However, our initial findings suggest that both the resistant and susceptible parent contribute to the resistance level in the progeny. Therefore care must be taken in the selection of resistant parents and test crossing with a range of elite selections and cultivars should improve our efficiency of producing resistant families.

Figure 7 A segregating family for raspberry root rot resistance. Untreated control plants are in the right-hand row and treated plants are to the left.

Root rot is a problem on a global scale and as such has provided opportunities for collaboration. Dr Patrick Moore of Washington State University (WSU) in the

United States has provided SCRI with resistance x susceptible seed lots as well as BC_3 generation seed from initial crosses to a putative accession of *R. innominatus* from Russia that has shown consistent resistance under field conditions in Washington. Currently, we are assessing this seedling material for root rot resistance and will generate BC_4 seed and share this with WSU. In addition, we have supplied WSU with samples of seed from resistant x susceptible crosses made at SCRI.

There may be no single trait as important in raspberries as quality / sensory character of the fruit or processed product. A collaborative flexible-fund project between SCRI (Rex Brennan, Rick Harrison and Ronnie McNicol), the Hannah Research Intitute (Donald Muir), and BioSS (Tony Hunter) has developed sensory evaluation protocols for fresh and processed fruit. The sensory evaluation is performed by a 12 member panel at the Hannah Research Institute under the guidence of Donald Muir. Tony Hunter of BioSS has developed user-friendly computer software to produce rapid experimental designs and multivariate analsysis of the complex sensory data.

The sensory project has now developed robust sensory vocabularies to evaluate fresh and frozen/thawed raspberry fruit and juice. Recent research using these methods has identified a particularly interesting and important relationship between the fresh and frozen / thawed character of raspberry fruit. Fresh fruit characteristics do not necessarily predict the frozen / thawed chracter. This finding has now lead to changes in the fruit quality evaluation methods that should produce better Individually Quick Frozen (IQF) products in the future. Typically, the major emphasis in the evalution of seedlings has been on fresh flavour, but beginning this season, more selections will be made at the seedling stage and fruit samples will be frozen and IQF flavour assessed as an additional selection criteria. In addition, fresh and frozen samples of all advanced SCRI selections and several control cultivars will be assessed for sensory characters to develop a better understanding of this relationship between fresh and frozen fruit. Future projects will use these methods to study heritablilty of these sensory attributes to assess if these methods could be incorporated to an even greater extent in the programme.

Successful plant breeding requires collaboration between nearly all sectors of the plant sciences, including plant pathology, entomology, virology, physiology, molecular biology and statistics. SCRI provides expertise in all these areas, which allows the *Rubus* breeding programme to flourish and remain a world leader in *Rubus* cultivar development. But possibly the most important collaboration is with the customer. The close relationship of SCRI with the growers and processors through the SSFG Ltd keeps the direction of the programme focused on the goals and objectives that will make the greatest impact for the industry.

References

1 Williamson, B., Lawson, H.M., Woodford, J.A.T., Hargreaves, A.J., Wiseman, J.S. & Gordon, S.C. (1979). *Annals of Applied Biology* 92, 359-368.

2 McNicol, R. J. & Graham, J. (1993). *Acta Horticulturae* 352, 393-398.

Interactions between plant resistance genes, pest aphid populations and beneficial aphid predators

A.N.E. Birch, I.E. Geoghegan, M.E.N. Majerus[1], C. Hackett[2] & J. Allen[3]

Insects cause estimated losses of at least 13% of world food production, despite an expenditure of approximately US $7.5 billion annually on agrochemicals. Aphids are important pests of all major temperate crops, causing economic losses by direct feeding damage, by contamination with honeydew and associated fungal pathogens and by transmitting plant viruses that decrease yield and quality. Estimates for the U.K. alone indicate that annual crop losses due to aphid attack are in the region of £100 million. Crops

[1] Dept of Genetics, Cambridge University
[2] BioSS, Dundee
[3] ADAS, Wye