

RASPBERRY BREEDING

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WORLD PRODUCTION

Raspberries are grown in many parts of the world with production estimated at 482, 763 MT (2005) ([http:// FAOSTAT.FAO.ORG](http://FAOSTAT.FAO.ORG)). Europe is estimated to produce around half of all production (*Rubus idaeus* L.). This is an important high-value horticultural industry in many European countries, providing employment directly in agriculture, and indirectly in food processing and confectionary. Most raspberry production is concentrated in the northern and central European countries, although there is an increasing interest in growing cane fruits in southern Europe e.g. in Greece, Italy, Portugal and Spain. In many production areas, the fruit is grown for the fresh market, but in central Europe e.g. Poland, Hungary and Serbia, a high proportion of the crop is destined for processing. Major regions of production in North America include the Pacific North-West, California, Texas and Arkansas, as well as regions in New York, Michigan, Pennsylvania and Ohio. Chile, Argentina and Guatemala also have extensive production.

In Europe in particular, there has been increased interest in sale of raspberry fruits harvested from 'organic production' - farming based on methods relying entirely on crop rotation and avoidance of pesticide application (except certain substances currently permitted by the national regulatory authority for organic farming). However, with woody perennial crops the difficulties of maintaining healthy productive plantations over many years are profound and it is too early to judge the overall success of these ventures in *Rubus* cane fruits. Increasing popularity of autumn-fruiting raspberries, in which

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late season fruit is harvested from berries forming on the upper nodes of primocanes (Jennings and Brennan 2002), has extended the production season and the period of attack of some foliar and cane pests. Some very early spring fruits with high value can also be obtained from the remaining lower nodes of these over-wintered primocane-fruiting types. Primocane-fruiting raspberries tend to be grown in the warmer areas of Europe where the temperature in autumn is relatively high and there is little risk of early autumn frosts. Interest has also been shown in extended-season production under glass or under plastic structures in northern European countries, e.g. Belgium (Meesters and Pitsioudis 1993; Verlinden 1995) and the UK (Barry 1995) and now in the Mediterranean fringe e.g. Spain, and Greece, and this trend will affect their pest and disease status. To satisfy these production systems, long primocanes grown in northern regions, such as Scotland, are lifted, chilled and stored for long periods for planting in late spring for late summer harvest under plastic. The concept of extended-season-production has been so successful that by careful manipulation of plant dormancy cycle and flower initiation it is now possible to produce fresh raspberries in Europe for sale in almost all months

Fruit has become important in the human diet due to increased consumers awareness of healthy eating practices. In 2003, the global fresh fruit market was valued at £7.6 bn at current prices, having increased by just 3.9% since 1999. The fresh fruit sector accounts for 38.1% of the overall market and is gaining share due to continuing trend towards convenience food. Banana account the largest segment of the fruit sector with 22.5% of the market in 2003.

In term of soft fruit, strawberries remain the best selling soft fruit, but other fruit such as raspberry, are gaining popularities because the increasing all year round availability. Raspberries have always been attractive as fresh dessert fruits or for processing from frozen berries into preserves, purees and juices. It is interesting to see that raspberries were first used in Europe for medicinal purposes (Jennings 1988), but there is now heightened interest focused on these foods as major sources of antioxidants, such as anthocyanins, catechins, flavonols, flavones and ascorbic acid, compounds that protect against

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a wide variety of human diseases, particularly cardiovascular disease and epithelial (but not hormone-related) cancers (Deighton *et al.* 2000; Moyer *et al.* 2002). As a result, the consumption of these berries is expected to increase substantially in the near future as their value in the daily diet is publicised. A concerted effort by the public health authorities in Finland, for example, has promoted the consumption of small berry fruits to their populations (Puska *et al.*, 1990) and in 2002, a similar initiative was launched in Scotland (Berry Scotland Project www.berryscotland.com) though success here has yet be demonstrated.

RASPBERRY BOTANY

Raspberries belong to the genus *Rubus*, one of the most diverse in the plant kingdom, comprised of a highly heterozygous series of some 500 species with ploidy levels ranging from diploid to dodecaploid (Jennings, 1988; Meng and Finn, 2002). Members of the genus can be difficult to classify into distinct species for a number of reasons including hybridisation between species and apomixes (Robertson 1974). These domesticated subgenera contain the raspberries, blackberries, arctic fruits and flowering raspberries, all of which have been utilised in breeding programmes. The most important raspberries are the European red raspberry, *R. idaeus* L. subsp. *idaeus*, the North American red raspberry *R. idaeus* subsp. *strigosus* Michx and the black raspberry (*R. occidentalis* L.). *Rubus* subgenus *Idaeobatus* is distributed principally in Asia but also East and South Africa, Europe and North America. In contrast, subgenus *Eubatus* is mainly distributed in South America, Europe and North America (Jennings 1988). The members of subgenus *Idaeobatus* sp. are distinguished by the ability of their mature fruits to separate from the receptacle. For a list of *Rubus* species, subgenera and sections see Skirvin *et al.*, 2005).

Details of the growth cycle of raspberry have been described by Jennings 1988). Raspberries are woody perennial plants with a biennial cane habit (Hudson 1959).

Fruit is harvested annually from each plant, although both non-fruiting vegetative canes (primocanes) and fruiting canes (fructocanes) are present. This main season summer-fruiting crop is usually supported

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on a post-and-wire system designed to carry the weight of fruits and to protect canes from excessive damage due to wind, harvesting and cultivation. Primocanes are produced in numbers excessive to requirements for cropping in the following season so many must be removed by pruning in winter and early spring to reduce inter-cane competition and create an open crop canopy for efficient light capture. Old dead fruiting canes must also be removed by pruning after harvest. Such pruning operations remove sources of fungal inoculum from the plantation and are important for the long-term health of the crop.

Small (0.5-1.5 cm), white to pink flowers are initiated in the second year of planting. The gynoecium consists of 60-80 ovaries, each of which develops into a drupelet. There are 60-90 stamens. Raspberries produce copious amount of nectar and attract bees. The flowers of *Rubus* are structurally rather similar to those of strawberries, with five sepals, five petals, a very short hypanthium, many stamens, and an apocarpous gynoecium of many carpels on a cone-like receptacle. Raspberries are an aggregate fruit, composed of individual drupelets, held together by almost invisible hairs. The one-seeded drupelets are set together on a small conical core (Jennings 1988). In *Rubus* each carpel will develop into a small drupelet, with the mesocarp becoming fleshy and the endocarp becoming hard and forming a tiny pit that encloses a single seed. Each drupelet usually has a single seed, though a few have two. Fruiting begins in the second year of planting and in favourable conditions plantations can continue to fruit for more than 15 years. Fruit development occurs rapidly, taking only 30 - 36 days for most raspberry cultivars.

Primocanes and fruiting canes are in close proximity resulting in a complex plant-architecture that provides spatial and temporal continuity for pests and pathogens to colonise a range of habitats (Willmer *et al* 1986). The complex nature of the plant architecture also creates a barrier of foliage that impedes spray penetration of plant protectant chemicals, thus requiring specialised chemical application equipment (Gordon and Williamson 1988). Healthy plantations are expected to crop productively for more than 10 years, but this is only possible if the planting stocks and soils are free from persistent viral,

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bacterial and fungal diseases and certain pests, hence the importance of quarantine arrangements and certification schemes to protect the propagation industry and fruit production (Jones 1991; Smith 2003).

Raspberry roots spread completely across the inter-row space and these young canes ('suckers') developed from root buds (Hudson 1959; Knight and Keep 1960) must be removed, mechanically by tractor-mounted flailing equipment or by contact herbicides, to prevent competition of these suckers for light, water and nutrients with the crop.

GENETIC RESOURCES

Roach (1985) and Jennings (1988) gave accounts of the early domestication of red raspberry (*Rubus idaeus* L). During the 19th Century, the North American red raspberry (*R. idaeus* subsp. *strigosus* Michx) was introduced into Europe and subsequently crossed with the European sub-species (*R. idaeus* subsp. *vulgatus* Arrhen.). Five parent cultivars dominate the ancestry of red raspberry; 'Lloyd George' and 'Pynes Royal' entirely derived from *R. idaeus* var. *vulgatus* and 'Preussen', 'Cuthbert' and 'Newburgh' derived from both sub-species. Controlled crossing began slightly earlier in the US than the UK with the introduction of Latham in 1914 (McNicol and Graham 1992). Domestication has resulted in a reduction of both morphological and genetic diversity in red raspberry (Graham *et al.*, 1996; Haskell 1960; Jennings 1988) with modern cultivars being genetically similar (Dale *et al.* 1993; Graham and McNicol 1995). This restricted genetic diversity is of serious concern for future *Rubus* breeding, especially when seeking durable host resistance to intractable pests and diseases for which the repeated use of pesticides in some regions is ineffective, unsustainable or unacceptable for certain selected markets, such as 'organic production'. The gene base can and is being increased by the introduction of unselected raspberry clones and species material (Knight *et al.*, 1989). The time required to produce finished cultivars from this material however can be considerable particularly if several generations of backcrossing are required to remove undesirable traits.

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There are 30 *Rubus* breeding programmes in 19 countries, almost all of which are in Europe or North America. The Scottish bred cultivar 'Glen Ample', released in the mid-1990's now dominates the UK market (www.fruitgateway.co.uk), superceding older varieties such as 'Malling Jewel', 'Glen Clova', 'Glen Prosen' and 'Glen Moy'. Glen Ample along with 'Tulameen' and recently the new cultivar 'Octavia' dominate the UK market and acreage due to their desirable fresh market characteristics. Serbia is a major world producer and exporter of raspberries, producing one quarter of the world tonnage. 90% of the acreage is dominated by the North American cultivar 'Willamette'.

In recent years, consumer demand for fresh raspberries outwith the main production season has increased with high premiums being paid for fresh market raspberries. This demand is being met by imports from countries such as Spain, Portugal and Chile. Production of raspberries either side of the main season is achieved through protected cropping under polytunnels, or glass, using novel systems of production to manipulate flowering and fruiting. Protected cropping and out of season production in European countries is expanding so that in areas of southern Spain nearly 100% of fresh market raspberries are being grown under tunnels. The early season cultivar 'Glen Lyon' has a low chilling requirement which makes it suitable for re-propagation and manipulation of canes and is currently the ideal variety for this production system.

These protected cropping systems have been adopted by the UK industry to improve fruit quality and extend the season. Since the majority of fresh market production goes to large supermarket chains, the demand for good fruit quality, flavour and shelf life is high. In other European countries, Pacific Northwest-bred cultivars have led the industry, such as 'Meeker', 'Willamette' and 'Tulameen'. Primocane-fruiting cultivar 'Heritage' has led the industry in many countries. In Scandanavia, the hardy Norwegian variety 'Veten' has been the mainstay for many years, now 'Glen Ample' has taken the lead.

In the US, 'Meeker' and 'Willamette' developed in the mid-1900s are the primary cultivars although recent publicly developed cultivars 'Cowichan' and 'Coho' are being widely planted. Black raspberry (*R. occidentalis* L.) production has traditionally been concentrated almost

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completely in Oregon, 'Munger' and 'Jewel' being the leading varieties; however, a strong South Korean industry has developed over the past five years.

BREEDING PRINCIPALS

Rubus breeding is hampered by several genetic problems including polyploidy, apomixes, pollen incompatibility and poor seedling germination. The highly heterozygous nature of the germplasm requires evaluation of large seedling populations. Breeding is based on a generation by generation improvement in breeding stock through selection and intermating individuals showing promise of producing superior progeny. This average improvement in the progeny of breeding stock resulting from intermating selected parents is called response to selection. For a review see (Hansche 1983).

BREEDING OBJECTIVES

A survey in 2000 indicated that there are around 30 *Rubus* breeding programmes in 19 different countries mainly in Europe and North America. Breeding programmes sponsored by end-users or government funded programmes aim to develop appropriate germplasm enabling their particular industry to realize its potential and thus goals vary from programme to programme. Many are faced with the same challenges however as the industry requires cultivars with excellent quality, higher yield, greater pathogen resistance and adaptation. As new problems arise and new production systems are developed, breeding programmes are faced with meeting these demands with new cultivars. The core primary objectives in raspberry breeding programmes include: high quality fruit, good yield, shelf life and suitability for shipping, if for the fresh market, suitability for mechanical harvesting for the processing market, adaptation to the local environment and improved pathogen resistance. Future changes in environmental, cultural and agronomic practices within the industry will impact strongly on both the nature of the germplasm required for the future and also the likely pest and disease problems.

Fruit quality must always be the major objective of any fruit breeding programme. While many characteristics are important in the

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successful acceptance of new cultivars, fruit quality must be considered the premier factor. Flavour, appearance and shelf life are the main attributes of fresh market quality. Flavour is a highly subjective trait but can be broken down into multiple descriptors for taste, texture and other sensory characteristics. Good, acceptable raspberry flavour tends to be fruity, sweet and floral with some acidity and no bitterness (Harrison *et al*, 1999). Colour, brightness, size and shape contribute to appearance. A naturally dark colour can be perceived as overripe by fresh market retailers, whereas a darker colour is desirable for processing. Large size is an attractive characteristic to both consumers and producers as it is more cost effective to pick.

The biennial cropping habit of raspberry means that both fruiting and vegetative canes exist together. Plant habit is important in plantation management and has a major effect on yield potential. In summer fruiting types, the most important plant characteristics include number and height of young cane, consistency of bud break, internode length and lateral length and position. In primocane fruiting types the amount of branching and extent of lateral development on the primocanes are major yield components. In both types erect, spineless canes are desirable.

Machine harvesting of processing raspberries is the standard practice for most major raspberry production regions around the world and is essential where picking labour is expensive or unavailable. Despite advances in machine technology, it appears that the major improvements in harvesting will come from plant breeding (Cormack, 1989). No single attribute has been found to determine successful machine harvest-ability but a range of interacting traits governs harvest performance. A suitable genotype must have uniform strong vigour and good cane density with an upright habit. Medium length laterals with good fruit presentation is also desirable. Maturity, physical shape of the berry and receptacle all contribute to ease of pick. This will help ensure that a high percentage of uniform, ripe fruit with acceptable process quality and minimal green fruit are harvested throughout the season (Hall 2002).

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In the UK and Europe, a transformation in cultivation practices has occurred from outside field plantations to protected cropping systems. Such changes in agronomic practices affect plant growth, seasonality and fruit quality and have implications for a shift in pest and pathogen pressures. For example, in Scotland, where pests such as two-spot spider mite (*Tetranychus urticae*) and diseases such as powdery mildew (*Sphaerotheca macularis*) are not a problem in field plantations but occur readily in tunnel production systems. Recently, breeding programmes in the UK have responded to this change in production by trialling and selecting germplasm under protected cropping systems. This will help to identify suitably adapted germplasm for commercial trialling and eliminate the most susceptible seedlings early in the breeding process.

While fruit quality must remain the priority in any commercial breeding programme, the incorporation of novel resistance/tolerance to pests and diseases is regarded as essential for the development of cultivars suitable for culture under integrated pest management (IPM) systems. Sources of resistance in diverse *Rubus* sp. to many pests and diseases have been identified and exploited in conventional cross-breeding (Keep *et al.*, 1977; Jones *et al.* 1984; Jennings 1988; Knight 1991; Williamson and Jennings 1992). However, germplasm bearing single resistance genes, when planted over extensive areas, can eventually be overcome by the rapid evolution of new biotypes of pests so that new types of host resistance are required to sustain plant protection (Birch *et al.*, 2002; Jones *et al.*, 2002).

Pest and diseases of raspberry in Europe have been extensively reviewed in Gordon *et al.*, (2006). Major pest and diseases will be briefly discussed. Root rot, cane diseases and RBDV are problems world wide with aphids, cane midge and beetles serious problems in Europe.

Root rot diseases have always been a problem in North America but were not regarded as a problem in Europe until the 1980s when *Phytophthora* root rot emerged as a major problem of raspberry with outbreaks in the U.K. (Duncan *et al.*, 1987), Scandinavia and

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Germany (Seemüller1986) . Raspberry root rot became a serious problem throughout temperate Australia during the unusually wet years of 1994–1996 with *Phytophthora fragariae* var. *rubi* (Wilcox *et al.*, 1993) identified as the major causal agent. This disease is now the most destructive disease of raspberries. Affected canes die in the first year of growth or their buds fail to emerge at the start of the second growing season. Alternatively, emerged laterals wilt and die at any time from emergence until late in fruiting. The almost simultaneous outbreaks of a new disease across Europe in traditional raspberry-growing areas (e.g. raspberries have been grown in Tayside, Scotland for more than century) suggested that the disease had spread through the propagation network and had been distributed to farms in new planting material. Introduction of new and highly susceptible cultivars sought vigorously by industry was a major factor in disease spread.

The prevention of new outbreaks must become the underpinning philosophy in control strategies for root rot. Ensuring that the planting material is free of disease is most effective strategy. The pathogen is unlikely to be present widely in soil where raspberries have never been grown previously. Screening cultivars of red and other raspberries and wild *Rubus* species have identified potential sources of resistance. 'Latham' and 'Winkler's Sämling' were identified early as having significant resistance. Species material, such as *R. strigosus* and *R. ursinus* have also been identified. Genetic resistance through plant breeding offers a feasible and effective method of control, but because of the time involved in combining resistance with other desirable traits, e.g. fruit size and quality, it has not yet had the anticipated impact in commercial production. More research to find resistance genes and breeding is required especially marker assisted breeding. Future breeding plans with respect to root rot resistance are underpinned by attempts to develop molecular markers linked to resistance to improve and accelerate selection efficiencies (Graham and Smith 2002). It seems likely that this potent disease will be managed most effectively in the future by enhanced host resistance.

Botrytis cinerea accounts for severe losses in yield most seasons and can cause devastating losses post-harvest if control measures are inadequate, especially in regions with moderate rainfall during blossom and harvest. This pathogen is difficult to control because

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there are multiple infection sites and no strongly resistant cultivars available to growers. Unfortunately conventional breeding has yet to produce cultivars that are highly resistant to grey mould, although there are some cultivars and selections with high levels of resistance to cane botrytis (Williamson and Jennings 1992). However, considerable variation in resistance to botrytis fruit rot has been reported in *R. crataegifolius* and *R. occidentalis*. Resistance to cane botrytis has recently been mapped and association with *Gene H* conferring cane pubescence confirmed (Graham *et al.*, 2006).

Raspberry bushy dwarf virus (RBDV) is the most common virus of *Rubus* worldwide (Martin 2002). This is of greatest concern in North America, particularly in the Pacific Northwest where the virus has reached epidemic proportions, probably due to the planting of newer cultivars that lack resistance. RBDV is a pollen borne virus which may cause a crumbly fruit symptom with foliar symptoms ranging from none to a bright yellow chlorosis and in a few cultivars, there is a stunting of the plants. Not all infected plants show crumbly fruit. In black raspberry, RBDV does not cause significant fruit losses or symptoms but can reduce cane number and vigor. Since the virus cannot be controlled with chemical applications the best means of controlling RBDV is with the use of immune cultivars, however, the occurrence of resistance-breaking isolates (RB) pose serious problems for future control.

The large raspberry aphid (*Amphorophora idaei*) is the most important aphid species found on raspberry in northern Europe causing direct feeding damage to susceptible cultivars, but its major importance is as a vector of raspberry viruses that cause serious decreases in plant vigour (Jones, 1986; Birch and Jones 1988). Raspberry cultivars containing genes for resistance to the large raspberry aphid have been in commercial use in the UK for more than 40 years (Briggs 1965). The resistance largely depends on two single major genes that control aphid numbers and subsequently the spread of the viruses they transmit (Jones 1986). Unfortunately, virulent biotypes of *A. idaei* that can break these specific resistance genes in their raspberry host plants have now developed Birch *et al.*, 1994; Birch *et al.*, 2002).

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The raspberry beetle (*Byturus tomentosus* De Geer) is a major pest of cultivated raspberry and hybrid berries in many countries of Europe and frequently found in fruits of wild raspberries and blackberries. Adult beetles can damage the buds and flowers by feeding on them in the spring and early summer but the most important damage in Europe is caused by larvae. They browse on the surface of drupelets on the developing fruit resulting in discoloured or contaminated ripe fruit leading to rejection or down-grading of the crop. This damaged fruit can become infected by botrytis (*Botrytis cinerea*) thus further reducing the storage of the ripe fruit (Woodford *et al* 2002). Wild *Rubus* species, including *R. coreanus*, *R. craetigifolius*, *R. occidentalis* and *R. phoenicolaesius* have been used as sources of resistance to raspberry beetle (Briggs *et al.*, 1982) in breeding programmes. As yet no commercial cultivars are available. Little is known about the mechanism(s) of resistance to raspberry beetle involved in wild *Rubus* species or crosses derived from them.

Feeding damage caused by raspberry cane midge (*Resseliella theobaldi*) larvae predisposes raspberry canes to the disease known as 'midge blight' which is responsible for major losses in raspberry in many parts of Europe (Woodford and Gordon 1978). In most of Europe, midge larvae only colonise splits in the bark of primocanes, but in Scandinavia larvae have been reported from splits in fruiting canes of the cultivars 'Veten' (Sorum and Stenseth. 1988) and 'Ottawa' (Dalman 1991). The raspberry cv. Glen Prosen, and the hybrid berries Tayberry and Loganberry, do not readily split their rind in the spring, and are rarely affected by 'midge blight' because female midges are unable to find suitable oviposition sites unless they are caused by mechanical means. Other *Rubus* species and crosses have been investigated as sources of resistance to raspberry cane midge. *R. parviflorus*, *R. odoratus* and F₂ crosses of *R. crataegifolius* x *R. idaeus* were found to be resistant when exposed to raspberry cane midges.

BREEDING TECHNIQUES

Breeding in raspberry is carried out by hybridizations between cultivars and /or species with desirable characteristics for multiple

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generations. Each cycle of crossing involves a cycle of glasshouse screening and field observation.

Crosses tend to be done out with the normal flowering period requiring dormant plants to be dug in autumn and placed in cold storage for around 6-10 weeks. Plants are then placed in a glasshouse at 18-21°C for 30-45 days for flowering.

MOLECULAR MARKERS IN BREEDING

Breeding methods used in raspberry have changed very little over the last 40 years or so. Little novel germplasm has made its way into commercial cultivars. However, with the narrowing genetic base coupled with the increasing demands from consumers, new breeding methods are required to meet demands. The speed and precision of breeding can be improved by the deployment of molecular tools for germplasm assessment and the development of genetic linkage maps. The development and application of molecular markers has been reviewed by Antonius-Klemola (1999), Hokanson (2001) and Skirvin *et al.*, (2005). The development of SSR markers (Graham *et al.*, 2002, Stafne *et al.*, 2005) has allowed the development of a raspberry genetic linkage map. This facilitates the development of diagnostic markers for polygenic traits and the identification of genes controlling complex phenotypes. Understanding the genetic control of commercially and nutritionally important traits and the linkage of these characteristics to molecular markers on chromosomes is the future of plant breeding. Red raspberry (*Rubus idaeus*) is a good species the application of such techniques, being diploid ($2n = 2x = 14$) with a very small genome (275 Mbp). Indeed, the haploid genome size of raspberry is only twice the size of Arabidopsis, making it highly amenable to complete physical map construction, thereby providing a platform for map-based gene cloning and comparative mapping with other members of the Rosaceae (Dirlewanger *et al.* 2004). The availability of abundant genetic variation in natural and experimental populations and adaptation to a range of diverse habitats (Graham *et al.* 1997b; Marshall *et al.* 2001; Graham *et al.* 2003) offers researchers a rich source of variation in morphology, anatomy, physiology, phenology and response to a range of biotic and abiotic

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stress. The ability to vegetatively propagate individual plants provides opportunities to capture genetic variation over generations and replicate individual genotypes to partition and quantify environmental and genetic components of variation of genetic linkage maps. These are necessary to develop diagnostic markers for polygenic traits and, in the future, possibly identify the genes behind the traits. The first genetic linkage of raspberry has recently been constructed (Graham *et al.* 2004). This 789 cM genetic linkage map was constructed utilising a cross between the phenotypically diverse European red raspberry cultivar Glen Moy and the North American cultivar Latham. SSR markers were developed from both genomic and cDNA libraries from Glen Moy. These SSRs, together with AFLP markers, were utilised to create a linkage map. An enhanced map with further SSR and EST-SSR and gene markers has recently been completed (Graham *et al.*, 2006). This work has highlighted the importance of maps and markers with demonstration of the tight association between *Gene H* and resistance to cane botrytis and spur blight (Graham *et al.*, 2006).

PROBLEMS AND UNKNOWNNS

For some breeding objectives, a lack of appropriate germplasm may seriously hamper progress. In these cases genetic manipulation may be the way forward (Graham *et al.*, 1996). This may not be possible in Europe in the near future however due to strong opposition from certain groups and sectors. Genetic manipulation in *Rubus* has been reviewed by Skirvin *et al.* (2005).

Most commercial raspberries are now maintained, propagated and sold as disease-indexed plants using micropropagation. Estimates of somaclonal variation of 1-3% per generation may be conservative with other estimates of 10% (Larkin *et al.*, 1989).

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