Currants and Gooseberries
Ribes species
Saxifragaceae

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INTRODUCTION

Ribes species, Saxifragaceae, are found throughout the temperate regions of Europe and North America, although species are also found in South America (notably Chile), Asia and northwest Africa. The genus consists of *about* 150 species, all shrubs or small bushes, spined or non-spined, and new species have been reported from South and Central America and parts of Asia in recent years. The range of habitats and plant types that comprise the genus shows considerable complexity and diversity.

The species used for commercial fruit productions include blackcurrant (*Ribes nigrum* L.), predominantly used for processing and valued for its high levels of ascorbic acid, red currant (*R. sativum* and related species), and gooseberry (*R. grossularia* and related species). The *Ribes* crops have been used as both foods and medicines for centuries. The crops are diverse, covering a range of fruit types and colors, and their production methods range from intensive large-scale mechanized farms for blackcurrant (Fig. 1) to small areas of hand-picked bushes for both redcurrant and gooseberry. Besides these three main crop types, there are also jostaberries, which are hybrids between *R. nigrum* and gooseberry species *R. grossularia* and *R. divaricatum*, designated *R.* × *nidigrolaria* (Bauer, 1986), which are grown predominantly for self-pick operations.

In addition to food uses, several species such as *R. alpinum, R. aureum, R. roezlii* (Fig. 2), *R. sanguineum* and *R. speciosum* have ornamental and landscape value, due to their ornate flowers and in some cases colored fruit.

World Production

The total global production of *Ribes* fruits in 2002, according to the Food and Agriculture Organization of the United Nations, was over 750, 000 tonnes of which *about*147, 385 t were gooseberries. In terms of crop volume, the most widely-grown crop is blackcurrant, where the main producer countries are Poland, Russia, the UK and Scandinavia. World production is increasing at the present time, partly due to the increased cropping potential offered by modern cultivars but also to the increasing interest in the nutritional benefits offered by *Ribes* fruit. Table 1 shows production levels of blackcurrant on a national basis.

In recent years production of blackcurrant has increased in eastern Europe including the Baltic states, China and New Zealand. Production of *Ribes* fruits in the USA has been restricted by legislation aiming to prevent the spread of white pine blister rust (*Cronartium ribicola* Fisch.), of which *R. nigrum* and other species are alternate hosts. However, with this legislation becoming less widespread now and the availability of resistant cultivars, there is increasing interest in some regions.

Redcurrants are mainly grown in Poland and Germany, with lesser production in France, Belgium and Holland. In the latter two countries, fruit is often produced in glasshouses outwith the main field cropping season. Gooseberry production has shown a steady decline over the past 15 years, with Germany, Russia and Poland the main producers.

Uses and Nutritional Composition

Blackcurrant is largely cultivated for processing, and the fresh market outlets, especially in Western Europe, are somewhat restricted. However, consumer trends towards healthier diets have led to increased interest in all berry fruits, and there are small increases in fresh market blackcurrant production, often under protection, with large-fruited cultivars (Fig. 3). The majority of the production in the UK is for juice, with the crop being grown under contract to processors for a pre-determined price, and the cultivar requirements are consequently aligned with the needs of the juice processing industry. Other uses for blackcurrant fruit include dairy products, such as yoghourts, jams, jellies and liqueurs, notably the French cassis. Buds of blackcurrant are harvested in some parts of France and Tasmania for their essential oil, which is used in the perfume industry. Redcurrants are generally used fresh for culinary purposes or for jams and other processed fruit preparations, while gooseberries are generally found in small quantities in the fresh market or in purees, preserves, and jams.

The composition of *Ribes* fruits is shown in Table 2. Ascorbic acid (vitamin C) one of the main nutritional components found in *Ribes*, and blackcurrants are particularly rich in it, with levels in commonly grown cultivars ranging from 130 – 200 mg/100 ml juice, to over 350 mg/100 in some breeding lines and even higher in wild accessions of *R. nigrum* var. *sibiricum*. Redcurrants and gooseberries generally contain considerably less ascorbic acid, around 30 mg/100g fruit. Some reports suggest that the ascorbic acid contained in blackcurrant fruit is more stable than most other sources, possibly due to the protective effects of anthocyanins and other flavonoids within the berries. The main period of ascorbic acid accumulation coincides with the berry expansion phase, soon after fertilization, and genotypic rankings of = content established in this early stage remained constant thereafter (Viola et al., 2000).

Antioxidant activity in foodstuffs has become increasingly important as a means of protection against cellular damage from active oxygen species that are implicated in the development of various human ailments, including cardiovascular disease, cancer and ageing effects. *Ribes* species, especially blackcurrants and related types, are outstanding sources of antioxidants, both in the form of high ascorbate levels but also in the high concentrations of polyphenolic compounds that are contained within the fruit (Lister, 2002). The latter include flavonoids, such as anthocyanins and flavonols. The amounts of these compounds in the berries vary with cultivar, environment and agronomic practices. Moyer et al. (2002) report a range of anthocyanin contents within blackcurrant cultivars of 128 mg/100g fruit to over 400 mg/100g, and the highest antioxidant activities were correlated with phenolic content.

The main anthocyanins in blackcurrant are cyanidin-3-rutinoside, delphinidin-3-rutinoside, delphinidin-3-glucoside and cyanidin-3-glucoside, and the relative proportions vary between genotypes. For example, a survey of available germplasm has shown that western European cultivars contain more cyanidin derivatives, whilst Scandinavian cultivars contain a higher proportion of delphinidin derivatives. Since the latter are generally more stable, many breeding programmes have preferentially selected for a high delphinidin:cyanidin ratio (Brennan, 1996). There are also minor compounds, such as cyanidin-3-sophoroside, delphinidin-3-sophoroside and pelargonidin-3-rutinoside, which collectively amount to ca. 5% of the total anthocyanins.

The stability of these nutritionally important compounds in blackcurrant during processing has been assessed, and whilst juice processing can cause considerable losses of ascorbate, the phenolic compounds are relatively stable during processing and antioxidant activity is retained in the juice. However, there may potentially be changes caused within the phenolic compounds by the processing, which may affect bioavailability. There are at present various studies worldwide, involving clinical trials, to ascertain how much of the ingested blackcurrant phenolics are actually taken up by the body and thereby play a role in proposed health benefits from berry consumption.

Other *Ribes* species have been found to have even higher levels of total phenolics and antioxidant activity; *R. valdivianum*, a Chilean species, was found by Moyer et al. (2002) to have extremely high activity, and an accession of *R. sanguineum* was found by Deighton *et al*. (pers. comm.) to have activity considerably in excess of the highest blackcurrants. This raises the possibility of breeding for improved antioxidant activity, although other less desirable traits found in these species, eg. poor flavor, must also be considered.

Redcurrant anthocyanins are mainly forms of cyanidin-3-glycosides, and most gooseberries contain only this compound plus cyanidin-3-rutinoside. This leads to a lack of color stability in many redcurrant and gooseberry products such as juices.

There has in recent years been increasing focus on sensory traits in berry fruits, and the selection of blackcurrant cultivars with superior characteristics in their juice profiles is now an important component of many breeding programs. Genotypic variation in sensory profile and the development of a working vocabulary was reported by Brennan *et al.* (1997), and further research showed that the sensory attributes associated with genotype persist in processed juice products. Some other *Ribes* species have been associated with the transferal of off-notes in the flavor of progenies developed from them, e.g. *R. ussuriense* and *R. petiolare*.

Seed oils of *R. nigrum* are marketed as a health supplement due to their high content of γ–linolenic acid (GLA) and other nutritionally important fatty acids. The content of GLA varies between genotypes, with a maximum of over 20% of total fatty acids in some lines.

BOTANY

Taxonomy and nomenclature

Different opinions have existing for almost 100 years on whether currants and gooseberries form a single genus (*Ribes*) or two genera (*Ribes* and *Grossularia*). The single genus proposal favored by Janczewski (1907) and others is well-founded on the basis of morphology, crossability and molecular sequence data. The *Ribes* genus has generally been placed in the Saxifragaceae, although some recent workers classify *Ribes* as part of the Grossulariaceae.

The division of the *Ribes* genus into subgenera has also been widely debated – six subgenera exist, according to Janczewski (1907), although nine were proposed on the basis of fertility of intrasubgeneric hybrids (Keep, 1962) and 12 by proponents of the two-genus theory such as Berger (1924). The main subgenera with crop and related species are: Coreosma (Eucoreosma in some classifications) – blackcurrants; Ribesia - redcurrants; and Grossularia – gooseberries.

Description

The variation of plant type within *Ribes* is considerable, in both fruit color and plant form. Most species are shrubs of 1.5-2m height, although some species e.g. *R. divaricatum* can grow taller. There are both spined and non-spined species, and a few species found in warmer regions are evergreen, e.g. *R. speciosum*. The main geographical centres of diversity for *Ribes* are in North America, northern Europe and Scandinavia, and parts of Russia extending into Asian sectors.

The most commercially important species is *R. nigrum*, found in northern Europe and northern Asia. Various subdivisions of *R. nigrum* are recognized, notably subsp. *scandinavicum* and var. *sibiricum*. Other important blackcurrant species within the Eucoreosma are *R. dikuscha* from Russia, *R. ussuriense* from Asia, *R. pauciflorum* from eastern Siberia, *R. bracteosum* and *R. petiolare* from the western USA, *R. hudsonianum* from northern USA and *R. americanum* from the mid-northern USA.

Redcurrants of the subgenus Ribesia, all spineless shrubs, are mainly derived from northern Europe, although there are species from North America such as *R. triste*. The main species involved in the domestication of redcurrants are *R. sativum*, *R. petraeum*, *R. rubrum* and *R. multiflorum* (Fig. 4).. White and pink currants are colour forms of *R. rubrum*.

Gooseberries from the subgenus Grossularia are characteristically spined at the nodes. The main species in Europe is *R. grossularia*, found throughout northern Europe, and this forms the basis for the commercial cultivars grown in Europe. North America is a main centre of diversity for gooseberry germplasm, and species such as *R. hirtellum* have been used extensively in breeding. Other important species are *R. divaricatum* from North America, *R. oxycanthoides* (also from North America) and *R. aciculare* from Russia.

Other important subgenera of *Ribes*, as defined by Berger (1924), include Symphocalyx, the golden currants (eg. *R. aureum* and *R. odoratum*), and Calobotrya, the flowering currants (eg. *R. sanguineum*). There are also several instances of interspecific hybridisation in *Ribes*, eg. *R. Gordonianum* (= *R. sanguineum* × *R. odoratum*) and *R. Carrierei* (= *R. glutinosum albidum* × *R. nigrum*) and *R. fuscescens* (= *R. bracteosum* x *R. nigrum*), forming species that have become established in their own right.

All species and cultivars of *Ribes* are diploid ($2n = 2x = 16$). Chromosomes are relatively small, and highly uniform apart from one pair with a satellite. Assessments of genome size using flow cytometry gave an average figure of 2ºC = 1.91 pg DNA for the redcurrant species *R. petraeum* and *R. rubrum* and the gooseberry *R. uva-crispa*.

Reproductive biology

The majority of *Ribes* species are monoecious, although a few dioecious types such as *R. alpinum* and *R. glaciale* exist. *Ribes* species generally produce flowers on second-year wood, and the flowers are borne on racemes (or strigs) that can reach over 20 cm in length in some species. Most blackcurrant strigs are ca. 10 cm in length bearing 6-9 flowers. Flowers are usually inferior and pentamerous, with colored calyx and sepals, and they develop at different times along the strig, basal flowers first. The fruit is a berry, usually with many seeds.

Most *Ribes* are insect-pollinated, although self-pollination can occur, especially in flowers that have both anthers and stigma at the same level. Most modern blackcurrant cultivars are almost fully self-fertile, although other *Ribes* species show differing levels of self-compatibility (see Brennan, 1996).

Floral initiation generally occurs between July and late August in the northern hemisphere, and is affected by environmental conditions and geographical location. Initiation is thought to proceed acropetally from the lower middle nodes. Flowering varies considerably between species, but most blackcurrants in the UK flower in April, with redcurrants slightly earlier. Flowering duration is generally 3-4 weeks, although historical data show that in the UK flowering has become earlier and more protracted in recent years, possibly due to changes in climate.

Many *Ribes* species, especially blackcurrant, have flowers that are highly sensitive to spring frost damage by temperatures < 8^{o}C, and much of the initial breeding work in the UK and other parts of Europe was aimed at producing new cultivars that were able to either withstand freezing temperatures at flowering or flowered sufficiently later to escape the most damaging frost events. The use of Scandinavian germplasm was initially beneficial in the development of UK-bred cultivars such as `Ben Lomond’ and `Ben

Sarek', but in recent years the incidence of serious frost events has shown a marked decline. In some parts of the UK, frost protection irrigation is used to protect blackcurrant plantations against damage.

Growth and development

Blackcurrants generally require between 800-1600 hours of temperatures below 7^{o}C depending on cultivar before buds will break in the spring (Barney and Hummer, 2005). Lack of chilling results in uneven bud break and poor eventual fruit quality at harvest, although if a cultivar has a low chilling requirement there is an increased risk of frost damage due to early bud break. Cultivars bred in low chill environments such as New Zealand have significantly lower chilling requirements than those from northern European climates. Similar differences in genotypic response to winter chilling levels have been reported for redcurrant.

Once buds have broken, new shoots develop from vegetative buds, at a rate determined by the overall vigour of the cultivar, together with the environmental conditions in which the bush is grown. Leaf expansion and development is generally accelerated at higher temperatures. The lateral buds of most European blackcurrant cultivars cease growth around the end of July, at which point the bushes enter dormancy. Once dormant, *Ribes* plants are very cold-hardy; fully acclimated plants can withstand temperatures of -30º to -40^{o}C, and some species such as *R. procumbens* are reputed to be hardy down to -60^{o}C.

Spines along the stem surface are a characteristic of gooseberry, although newer spinefree cultivars – or at least less spiny cultivars such as `Pax' - are becoming more prevalent. The genetic control of spines appears to be fairly complex. Most spinefree types are derivatives of *R. hirtellum*, although yields are low and fruit size poor in most of them. One of the *R. hirtellum* derivatives, `Spinefree', has been used in backcrossing programmes with *R. grossularia* to improve the agronomic traits, but further development is required.

The fruit size required in commercial cultivars of blackcurrant depends on its end-use; for the fresh market large berries of up to 3 g are preferred, for ease of picking and attractive presentation. However, for juice processing, smaller berries are required (*ca*. 1 g), since most of the anthocyanins and other desirable components are located in the outer layers of the fruit, although if the berries are too small they can prove difficult to process. Larger berries are preferred in both redcurrant and gooseberry, and evenness of ripening along the strig is also important in redcurrant cultivars.

HORTICULTURE

Propagation

Ribes species are usually propagated by hardwood cuttings, which root easily in most conditions. The usual procedure is to take 15-25 cm cuttings in the fall from dormant bushes, and either retain in sandbeds over winter before spring planting or plant directly into nursery rows immediately after cutting. The latter method gives a high success rate in blackcurrant, although less so in gooseberry.

Other methods of propagation that are commonly used, especially for gooseberry, include softwood cuttings, taken in late spring and rooted under mist before growing-on, and single-bud cuttings. Micropropagation of *Ribes* has been successfully deployed, especially for *R. nigrum*, where rapid increases in plant numbers are required, although *in vitro* performance is highly variable between cultivars.

Seed propagation is not commonly used outwith the propagation of hybrid lines in breeding programmes (Fig. 5), and most protocols for *Ribes* seed germination involve stratification at 2-4^{o}C for 12-14 weeks and subsequent temperatures of 16-20^{o}C.

Rootstocks

Whileit is possible to develop tree forms of some *Ribes*, notably gooseberries, on their own roots, it is also possible to graft scions of the fruiting cultivar onto suitable rootstocks. In most instances where this is done, e.g. parts of eastern Europe such Hungary, *R. aureum* is used as the rootstock (mainly the clones 'Brecht' and 'Pallagi 2'), due to its vigorous growth, wide graft compatibility and reduced suckering.
Similar use of rootstocks in redcurrants has been reported, with *R. aureum* again proving useful with cultivars of low vigour such as `Junifer'.

Training and pruning

Bush density in blackcurrant plantations has increased significantly over the past 10 years, so that most UK growers now plant at *ca*. 11k bushes per hectare, with spacings of 30-35 cm within rows. The rows are usually around 3 m apart, to allow mechanical harvesters and other crop machinery to pass through easily, and many growers now plant grass between rows to reduce herbicide use.

Pruning requirements are kept to a minimum using the high-density plantings outlined above, with most growers simply taking out branches growing excessively outwards from the row or damaged during harvesting. Plantations may be cut down to ground level after 5-10 years growth, and allowed to regenerate. The loss of a year's cropping after cutting down is offset by the reduction in pruning costs.

Bushes for self-pick operations or for the fresh market are generally planted a little wider apart, and occasionally are grown on wires for support (FIG). When grown as single bushes, blackcurrants are placed at wider spacings of *about* 1 m within rows. Pruning is done to develop a cup-shaped bush with a range of wood ages by years 4 onwards, to maximise cropping. For gooseberries, the usual method of management in the UK is to allow the bushes to grow on a single stem (or leg), above which the bush is pruned to give an open habit.

Cordon-grown *Ribes* plants, especially gooseberries and redcurrants, are used for fresh market production in some countries, and are also found in old traditional walled gardens in the UK. The various methods for achieving the desired growth over a long period are detailed in Barney and Hummer (2005)

Fertilization

Controlled applications of fertilizer are important for the production of high yields of good quality fruit of blackcurrant and other *Ribes* crops. However, excessive fertilization can have negative effects on growth habit and also on disease incidence; for example, excessive nitrogen can lead to increased mildew on the resultant new growth.

Top dressing of blackcurrant plantations with nitrogen is often done in Europe, from April to June, at up to 25 kg/ha per application. Phosphate application, primarily to promote root development, is especially important during establishment, and annual applications are generally around 37 kg/ha. Lack of potash often leads to poor growth habit, reduced berry weight and low yields, and annual applications of 100-120 kg/ha are recommended in Europe.

Diseases and pests

Mildew (*Sphaerotheca mors-uvae* (Schw.) Berk.)

This fungus infects *Ribes* leaves, shoot tips and on some species, eg. *R. grossularia* in severe infections, the fruit as well, rendering it useless. First recorded on gooseberries in Ireland in 1900, it spread to epidemic proportions throughout Europe by the 1960s on both gooseberries and blackcurrants. For older susceptible *Ribes* cultivars, especially of gooseberry, mildew remains the major limiting factor to successful cultivation. Control of mildew on susceptible cultivars is dependent on frequent fungicide applications, and the development of resistant types is a breeding objective in most modern *Ribes* programmes. Modern cultivars that are resistant to mildew include `Ben Hope', `Ben Gairn', `Ben Dorain', the Polish cultivars `Tiben' and `Tisel' and the Russian `Pilot Alexander Mamkin'.

S. mors-uvae produces new races that can often overcome resistance; for example, the cultivar `Ben Lomond' was resistant when released in 1972 but is now completely susceptible. However, other cultivars have remained resistant for over 50 years, with the resistance attributed to epidermal cell developmental factors. The Swedish cultivar `Sunderbyn II', a selection from the wild, and other wild ecotypes of *R. nigrum* from northern Scandinavia and Russia have been reported to possess strong resistance to a wide spectrum of races of *S. mors-uvae*, leading to suggestions of a putative linkage between resistance and winter hardiness. Another resistance gene, designated *M*, now conferring only partial resistance, is also derived from wild northern *R. nigrum* populations, and is found in the Finnish cultivar `Brödtorp'. Other forms of *R. nigrum* var. *sibiricum* and *R. dikuscha* are also regarded as good donors of resistance.
A series of dominant genes for resistance, the *Sph* genes, were found in various *Ribes* species including *R. carrierei* Schneid., *R. oxycanthoides* and *R. sanguineum*. Other currant species showing resistance include *R. aureum*, *R. americanum*, *R. hudsonianum*,

R. odoratum and *R. pauciflorum*.

In redcurrant, the cultivars `Fay's Prolific', `Houghton Castle', `Jonkheer van Tets', `Red Lake' and `Rondom' are among those resistant to mildew, whilst in gooseberry the UK cultivars `Pax' and `Invicta' are resistant, together with North American cultivars derived from *R. hirtellum* (eg. `Houghton') and *R. oxycanthoides*.

Blackcurrant Reversion Disease (BRD)
This is by some distance the most serious viral disease of *Ribes*, particularly blackcurrant. The causal agent, after many decades of research, has been identified as blackcurrant reversion virus, a virus of the genus *Nepovirus*, and subsequent development has led to PCR-based detection protocols that allow *Ribes* plants to be tested for reversion within days rather than the 2 years required using biological tests. The sole vectors for the transmission of reversion are Eriophyid mites of the genus *Cecidophyopsis* (see below), and the effect of the virus after infection is to render the bush sterile, although this commonly takes 2 or more years to develop systemically throughout the bush. Reversion occurs in all regions where currants are grown, with the exception of the Americas and Australia (Jones, 2002). In addition to blackcurrant, reversion affects redcurrants, although much less severely; gooseberry, however, appears to be immune. Other *Ribes* species that are affected by reversion virus include *R. alpinum*, *R. bracteosum* and *R. spicatum*.

Two forms of the virus have been described (Jones, 2002), namely the common European form (designated E) and a more severe R form from Finland and countries of the former Soviet Union. The forms differ both in the severity and type of symptoms, although both lead to leaf abnormalities. On flowers, a marked lack of pubescence on the buds and an increase in colouration is obseverd, while the R form also causes division into ten instead of five petals, loss of stamens and elongation of the style. In redcurrant, the symptoms on both leaves and flowers are less pronounced.

Control of reversion disease relies on reduction of the mite vector, through resistant cultivars or chemical means (predominantly sulphur applications), together with the removal of reverted bushes from plantations as soon as diagnosed.

Resistance to reversion is found in *R. aureum*, *R. cereum*, *R. dikuscha*, *R. fuscescens* Jancz. (= *R. bracteosum* x *R. nigrum*), *R. gordonianum* Lem. (= *R. sanguineum* x *R. odoratum*), *R. longeracemosum* Franch., *R. pauciflorum* and *R. nigrum* var. *sibiricum*. Resistant cultivars of blackcurrant are usually derived from *R. nigrum* var. *sibiricum* or *R. dikuscha*; the latter include `Golubka' and the Scottish cultivar `Ben Gairn', both of which show resistance to both the E and R forms of the virus.

Gooseberry Vein Banding Disease (GVBD)
As with reversion disease, the aetiology of GVBD has been the subject of research extending over many years, but a badnavirus, Gooseberry vein banding associated virus (GVBAV), has been found to be strongly associated with the disease, although other components may also be involved (Jones, 2002).

The symptoms of GVBD are chlorosis of the lamina adjacent to the main veins of leaves, and can be found on blackcurrant, redcurrant and gooseberry. The symptoms may be restricted to just part of the leaf, and gooseberry is generally affected more severely than the other *Ribes* fruits. There is some experimental evidence for reduced growth and yield of redcurrant and gooseberry caused by GVBD, and similar effects in blackcurrant are likely.

Transmission of GVBAV is thought to be by aphids, especially *Nasinova ribisnigri* and *Hyperomyzus lactucae*. Few if any highly resistant cultivars of *Ribes* have been identified, although resistance/tolerance of GVBD has been reported in *R. divaricatum* and *R. sanguineum*. Establishment of plantations with high-health stocks, removal of infected plants and control of the putative aphid vectors represent the main means of controlling the spread of GVBD.

<u>Leaf spot (*Drepanopeziza ribis* (Kleb.) von Höhn.)</u>
This fungal disease occurs throughout Europe, North America and Oceania, and produces necrotic lesions which develop further into premature defoliation in severe cases, leading to reduced crops in subsequent years. The levels of infection are increased in wet years, due to splash dispersal of spores. Morphologically distinct races have been found on blackcurrant, redcurrant and gooseberry respectively: all seem to be capable of infecting the other two species whilst being most pathogenic on their original host. Control measures depend on chemical sprays and the removal of infected leaves after abscission. Resistance is controlled by two complementary genes, Pr_1 and Pr_2 (Anderson, 1972), and potential sources of resistance include *R. dikuscha*, *R. nigrum* var. *sibiricum*, *R. americanum*, *R. aureum* and *R. glutinosum*. Screening for resistance is routine in most modern blackcurrant breeding programmes, and the majority of new cultivars have reasonable resistance to *D. ribis*.

R. petraeum is the main source of resistance in redcurrant, along with *R. multiflorum* and some of its derivatives, while in gooseberry resistance is found in *R. divaricatum* and North American genotypes such as *R. oxycanthoides* and derivatives.

<u>Rust (*Cronartium ribicola*)</u>
Ribes spp. occupy an important role in the lifecycle of this disease, and as a result there is an urgent need for resistant cultivars for areas where susceptible pines are grown. The generally observed symptoms of infection on *Ribes* are lesions and developing uredinia on the leaf abaxial surfaces, with eventual loss of leaves. However, the implications for forestry plantations of susceptible *Pinus* spp. are often more serious, leading to death of trees and unviable plantations. Further details of the origin and spread of this fungus can be found in Hummer (2000) and other contributions in the same journal.

A dominant gene for resistance to *C. ribicola*, designated *Cr*, was found in *R. ussuriense*, and was incorporated in commercial blackcurrant germplasm in Canada in the 1940s, leading to the resistant cultivars `Consort', `Coronet' and `Crusader'. Further development in Sweden produced the resistant cultivar `Titania', and breeding for rust resistance is now increasing in importance. Other resistant Eucoreosma species include *R. pauciflorum*, *R. nigrum* var. *sibiricum*. Redcurrants also show cultivar differences in resistance, and *R. petraeum* and *R. rubrum* are both sources of resistance. Gooseberry is generally less susceptible than the currant species.

Septoria leafspot (*Septoria ribis* Desm. teleomorph *Mycosphaerella ribis* (Fückel) Kleb.)
This disease is only of occasional and minor importance in Europe and North America, but is more serious in areas such as New Zealand, where it can be the most serious fungal disease of blackcurrants. Symptoms include necrotic foliar lesions, leading to premature defoliation and lower yields. Race structures have been described for the causal agent, and resistance has been reported in *R. nigrum* var. *sibiricum*, *R. dikuscha* and *R. americanum*, with three resistance genes described in the latter. Derivatives of these species have also been reported as resistant. Most resistant gooseberries are derived from *R. divaricatum.*

Botrytis
The effects of *Botrytis cinerea* on *Ribes* can be either die-back of the shoots and fruit rot, and also to increase levels of premature fruit drop or `run-off'. Botrytis can enter the plant through wounds caused by pruning or mechanical harvesting, which can lead to stem death. Considerable variation in susceptibility to these effects has been found in blackcurrant germplasm. Fruit rot levels in blackcurrant are affected by the strength of the skin, and fruit that can be removed without tearing of the skin at harvest are considerably less prone to *Botrytis*-led spoilage.

Run-off in blackcurrant and redcurrant can cause serious losses in some years, and differences in cultivar susceptibility have been found. Although various factors, mainly physiological, have been proposed as the cause of run-off, *B. cinerea* has been found to cause frequent symtomless latent infection of the flowers that leads to premature shedding of immature fruit. The main sources of resistance to `run-off' are cultivars and species accessions from northern regions, e.g. Scandinavia.

Gall mite (*Cecidophyopsis ribis*)
This species is probably the major pest of blackcurrant worldwide, although it has not been reported from North America or Tasmania. Besides causing swelling of the buds (known as `big bud'), it is also the vector of blackcurrant reversion virus. The mites emerge from the buds in springtime, to be dispersed as the buds open. Mites may move short distances along the infested plant to new buds, or may be carried on the bodies of insects or birds, but the vast majority are spread passively by wind or rainsplash. Since a single galled bud can contain up to 35 000 infective mites, and an infested bush can contain over 100 galls, the build-up of inoculum within an affected plantation can be dramatic. There are few chemical controls now available for *C. ribis*, with sulphur sprays being preferred within Europe. Removal of affected bushes, and ultimately infested plantations, is a vital means of reducing spread to new plantations, especially since bushes infected with blackcurrant reversion disease are more susceptible to mite

colonisation and reproduction.

Cecidophyopsis mites have been isolated from various *Ribes* species, and the host-pest relationships have been greatly clarified by the use of molecular techniques, allied to morphometric analyses (summarised by Amrine *et al*., 1994). The mites found on cultivated *Ribes* species are confirmed as distinct species, so that *C. ribes* infests blackcurrant, *C. selachodon* infests redcurrant and wild redcurrant species (*R. spicatum*) and *C. grossulariae* infests gooseberry. Additional species of *Cecidophyopsis* that produce galling were also identified, namely *C. alpina* on *Ribes alpinum*, *C. aurea* on *R. aureum* and *C. spicata* on *R. spicatum*. Since *R. alpinum* and *R. spicatum* are known to be naturally infected with blackcurrant reversion virus, it suggests that the associated mite species *C. alpina* and *C. spicata* may also be able to act as vectors of BRV.

Resistance to gall mite has been a breeding objective in most blackcurrant programmes for many years (Brennan, 1996). The most effective source of resistance used so far in western Europe is the *Ce* gene from gooseberry, and the introgression of this gene into *R. nigrum* is described by Knight *et al*. (1974). A long-term backcrossing programme to restore acceptable fruiting characters was undertaken, latterly at the Scottish Crop Research Institute, and potential new cultivars with resistance to *C. ribis* are now approaching commercialization.

Aphids

Twelve aphid species have been described on *Ribes*, although only seven are of economic significance, either as virus vectors (see above) or causing damage to growing shoots and leaves. In Europe, the most damaging species are *Hyperomyzus lactucae*, *Cryptomyzus galeopsidis*, *Cryptomyzus ribis* and *Aphis schneideri*. Development of appropriate IPM strategies to control aphids in *Ribes* plantations, including the use of entomopathogenic fungi, is in progress. There are differences in aphid susceptibility between cultivars, and field discard of the most susceptible lines is practiced by most breeders.

Blackcurrant Leaf Curling Midge (*Dasineura tetensi*)

This pest of blackcurrant is difficult to control using conventional means, as it can go through up to 4 generations within a single summer. Its occurrence in many growing areas, particularly in Europe, had reduced due to the widespread use of broad-spectrum pesticides for control of gall mite. However, the progressive withdrawal of such chemicals and the increasing interest in IPM strategies mean that an increase in leaf midge levels has already begun. Work to identify suitable natural predators of the midge such as *Platygaster* spp. that can be used in an integrated control system is in progress.

Differences in susceptibility exist between blackcurrant cultivars, and the main sources of resistance within the Eucoreosma are in *R. americanum*, *R. dikuscha* and *R. ussuriense*, although there is variation in the levels of resistance shown by different accessions of the latter two species. Resistance in *R. nigrum* cultivars such as `Ben Connan' appears to be due to larval antibiosis, rather than differences in volatile profiles. A dominant gene for resistance, *Dt*, was identified in *R. dikuscha* by Keep (1985).

Clearwing (*Synanthedon tipuliformis*)
This pest is prevalent in many areas of *Ribes* production, but is particularly serious in New Zealand. Crop losses of over 50% have been reported in blackcurrant, with some cultivars more susceptible than others and redcurrants particularly susceptible. Differences in cultivar susceptibility have been variously attributed to plant habit, wood hardness and variations in the volatile profile of individual cultivars. Considerable progress has been made on the development of pheromone-based controls which disrupt the mating pattern of the pest, and these controls are now used commercially.

Harvesting and fruit handling
The majority of the blackcurrant crop worldwide is mechanically harvested, and the present generation of harvesters is able to pick the fruit in a single pass with minimal losses (Dale et al., 1994). Hand-harvesting of blackcurrant for the fresh market is still practiced in Europe, although this sector of the market is relatively small. The development of mechanical harvesting has led to a change in growth habit of new cultivars; older types such as `Öjebyn' and `Brödtorp' have a tendency to prostrate growth, whilst more recent cultivars such as `Ben Tirran' and `Ben Hope' are much more upright, making them easier to harvest. `Ben Hope' obtains its erect habit from `Westra', a fastigiate mutant form of the old cultivar `Westwick Choice', and other donors of bush habit include *R. glutinosum* and *R. bracteosum*.

In addition to selection for growth habit, blackcurrant harvesting also makes demands in terms of branch strength. Stronger branches are now required to carry heavier crops without breaking or excessive bending, which would limit harvesting efficiency. Ideally, high mechanical strength in the branch timber is combined with elasticity at the base, so that branches borne down by the weight of crop return to an upright position after harvesting.

A further requirement for efficient mechanical harvesting is evenness of ripening. Since blackcurrant is a processing crop, it is most important that all fruit is at a similar stage of ripening at harvest. Uneven budbreak caused by lack of winter chilling often leads to uneven fruit ripening, and this may have implications for certain cultivars in various proposed climate change scenarios.

Mechanical harvesting of redcurrant is not common, due to harvester-induced injury caused by lack of branch flexibility. Additionally, the lack of fruit firmness and skin strength makes it difficult to harvest intact fruit. Gooseberry is also predominantly hand-harvested, although there are reports of successful mechanical harvest.

Blackcurrants are generally harvested into bins and either processed or frozen within 24 hours. Within the UK, over 90% of the blackcurrant production is used for juice, and the principles for juicing to retain as much of the quality and nutritional components as possible are described in Brennan and Harrison (2001). For the fresh market, the use of controlled atmosphere storage and packaging enables the fruit to be stored, usually on the strig, for considerable periods.

Main cultivars and breeding

Blackcurrant

The breeding and domestication of *Ribes* has taken place only within the last 450 years, with the first records of blackcurrants found in 17th century herbals referring to the medicinal properties of the fruit and leaves (Roach, 1985). The descriptions of the fruit in these references suggest that the initial selections were very close to wild types. Early selection was fairly erratic, but Keep (1995) suggests that there was probably selection for self-fertility, since selfed progenies of most cultivars show marked inbreeding depression. By the nineteenth century, a range of blackcurrant cultivars was available, including the cultivar `Baldwin' which is still grown in some parts of the UK. The number of available cultivars, all based entirely on *R. nigrum*, increased until in 1920 26 cultivars were classified into four main groups.

Throughout Europe, the `Ben' series of cultivars bred in Scotland at the Scottish Crop Research Institute are increasingly popular, occupying over 90% of the UK cropping area and *ca*. 50% worldwide. In recent years, the later-flowering cultivars `Ben Alder' (`Ben Lomond' x `Ben More') and `Ben Tirran' (from a complex cross involving `Ben Lomond', `Seabrooks Black' and `Amos Black') have been widely planted both in the UK and in eastern Europe. Newer releases such as the partially gall mite-resistant `Ben Hope' (a complex cross involving `Westra' and a blackcurrant x gooseberry backcross hybrid) (Fig. 6) and the reversion-resistant `Ben Gairn' (`Ben Alder' ×`Golubka') are becoming very popular within the UK and beyond.

In Scandinavia and Russia, most of the cultivars used until the early 20th century were based on wild selections from native germplasm, and some of these selections, eg. the cultivars `Öjebyn' and `Brödtorp' are still grown today. The cultivar `Titania' (a hybrid between the Russian *R. dikuscha* derivative `Golubka', the Canadian `Consort' and the old English `Wellington XXX') is now grown both within Scandinavia and also in Poland. It is also popular in North America, due to its resistance to rust.

In New Zealand, previously popular cultivars of blackcurrant such as `Magnus' are increasingly replaced by cultivars such as `Ben Rua' and `Ben Ard' (both originating from Scotland and selected in NZ). Cultivars bred at HortResearch in Lincoln such as `Murchison' (Ben Ard × EM1613/8) are growing in support.

Besides the programmes and regions mentioned above, active breeding programmes for blackcurrant are in progress in parts of Russia, Lithuania, Estonia, Hungary, Romania and Poland and China. The cultivars from these programmes are generally grown locally in the regions for which they are adapted.

Breeding objectives in blackcurrant have altered significantly in recent years, with fruit quality attributes, including ascorbic acid and anthocyanin content, total acidity and levels of soluble solids, now regarded as equally important as agronomic traits in many programmes, due to processor demands. The main agronomic goals are consistency of yield and resistance to pests and diseases. The latter is driven by the loss of many chemical controls and a widespread move towards Integrated Crop Management systems. Most breeding programmes are using other *Ribes* species as donors of specific traits, followed by backcrossing over several generations, and this trend is set to increase in the future.

Redcurrant

Of the species contributing to redcurrant development, *R. sativum* was first referred to in 1536 in France, *R. petraeum* soon after and *R. rubrum* very much later. By the 1920s, over 30 cultivars classified into five groups were identified in the UK. As in blackcurrant, some very old cultivars are still grown in small amounts today - `Red Dutch' and its white equivalent were first described in 1778.

Breeding of redcurrants in recent years has been much more restricted than for blackcurrant. In the UK, `Laxton's No. 1' was introduced in the early 1900s, after which very few cultivars have been produced in the UK apart from `Redstart' (`Red Lake' x [*R. multiflorum* x *R. sativum*]), bred at East Malling by E. Keep. Of popular cultivars from outwith the UK, the cultivar `Red Lake' was selected in Minnesota, USA, and `Fay's Prolific' was bred in New York, USA, possibly from a cross between `Victoria' and 'Cherry'. `Jonkheer van Tets' was raised in Holland from a seedling of `Fay's Prolific'. Most commercial production in Europe is now based on the Dutch cultivars `Rondom' (a *R. multiflorum* backcross), `Rovada' (`Fay's Prolific' × `Heinemann's Rote Spätlese) and `Junifer', a very early-ripening French type.

Whitecurrant breeding and resultant cultivars are considerably less common than the other currants. The most popular at the present time are `White Versailles', developed in France in the late nineteenth century from unknown parents, and newer types such as `Zitavia' from Holland. Breeding programmes for red and whitecurrants are now generally restricted to eastern Europe and Russia. The main objectives are improved yields, uniformity of ripening and resistance to leafspot.

Gooseberry

The first report of gooseberry in the UK is from 1275, when bushes were supplied to Edward I from France. The number of available cultivars increased dramatically throughout Europe, especially in the UK where the activity of amateur breeders led to over 1000 cultivars being listed by 1925. It is estimated that over 4800 gooseberry cultivars of various fruit colours have been named, although few have proven to be commercially useful. It is notable that, as with the other *Ribes* fruits, some very old cultivars are still grown, eg. `Whinham's Industry' (selected before 1850) and `Careless' (1860). The increase in American gooseberry mildew had a major effect in reducing commercial cropping areas in the UK and elsewhere, along with the labor-intensive and spiny nature of the crop. Breeding in the UK has produced the cultivars `Invicta' (`Resistenta' ×`Whinham's Industry') and `Pax' (Whinham's Industry ×a spineless, mildew resistant derivative of the Canadian cv Captivator and Lancashire Lad).

In North America, most initial cultivars were derivatives of R. hirtellum, such as `Houghton' and `Poorman', which are still grown today. Further use of native species such as *R. oxycanthoides* led to the production of types with reduced or absent spines (`Spinefree', `Captivator'). Further development has aimed to incorporate European-type fruit size into these American types.

Breeding of gooseberry is, as with redcurrant, generally restricted to eastern Europe, where there are still strong markets for the fruit, and cultivars are grown in localised areas for the most part. The main objectives are fruit size, reduced or absent spines and resistance to mildew.

A summary of some of the most commonly cultivated *Ribes* cultivars is shown in Table 3.

Molecular breeding and mapping

Molecular techniques have in recent years been applied to *Ribes*, mainly *R. nigrum*, and various marker types including RAPDs, AFLPs, SSRs and SNPs have been reported for the genus. The first genetic linkage map of *R. nigrum*, based on AFLPs and SSRs (genomic and EST-derived), has recently been completed (Brennan *et al*., 2008), and work to identify markers linked to traits of interest is in progress at various sites. The initial focus is on traits controlled by single genes, particularly those such as gall mite resistance that are difficult or time-consuming to screen for in the field, and in this case a PCR-based marker closely linked to the *Ce* resistance gene is currently undergoing validation. However, marker development and marker-assisted breeding strategies for early selection for fruit quality characters are priorities for the future. Effective deployment of markers in breeding programmes will enable the current generation time for new cultivars to be greatly reduced.

Germplasm collections

The availability of genetic resources for breeding is increasingly important in *Ribes*, particularly in view of the widespread use of interspecific hybrids and the considerable intraspecific variation found in many species. Most breeding programmes hold fairly small active collections, but more extensive resources can be found at the following sites:

- Vavilov Institute, Russia (www.vir.nw.ru)
- Nordic Gene Bank, Scandinavia (www.ngb.se)
- National Clonal Germplasm Repository, Corvallis, OR USA (http://www.ars-grin.gov/ars/PacWest/Corvallis/ncgr)

A database of European *Ribes* accessions from Poland, the Czech Republic, Germany, Romania, Lithuania and the UK is maintained at Vilnius University, Lithuania, under the aegis of the European Cooperative Programme for Crop Genetic Resources Networks at the following site:

http://www.ribes-rubus.gf.vu.lt

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Figures

Tables