History of the British Columbia Raspberry Breeding Programme

For more than 100 years, the United States Pacific Northwest (PNW) and the southwestern coastal region of Canada have been recognized as one of the world's premier red raspberry growing regions. Production extends from the Willamette Valley of Oregon, north through Washington and into the Fraser Valley of British Columbia (BC). The mild maritime climate and sandy loam soils are ideal for producing top quality fruit for both processing and fresh markets. Until recently, public sector agencies throughout the region have supported active research programmes to help realize optimum yields and quality. Among these agencies, the Agri-Food Canada (AFC)-sponsored breeding effort at the Pacific Agri-Food Research Centre (PARC) in BC has been a major influence in promoting raspberry production throughout the region.

The history of the BC programme is short compared to those of many other fruit breeding efforts, including several involving raspberry. The programme began in 1959 and continues, though in somewhat reduced circumstances, with much more funding coming from the private sector rather than from government. However, the programme has a long history compared to recently inaugurated programmes which are sponsored by a combination of public and private sector funding or entirely by the private sector.

The programme initially relied entirely on parents with genes derived from *Rubus idaeus* subsp. *vulgatus* Arrhen (European red raspberry) and from *R. idaeus* subsp. *strigosus* Michx. (North American red raspberry) (Daubeny 1996). The subspecies are often given species status and in this paper will be referred to as *R. idaeus* and *R. strigosus*, respectively. In more recent years, parents with genes derived from *Rubus occidentalis*

Hugh Daubeny, Emeritus Research Scientist
Pacific Agricultural Research Centre, Aggasiz, BC, Canada
Correspondence address: 3558 W 15th Ave., Vancouver, BC V6R 2Z4

L. (black raspberry), in addition to *R. idaeus* and *R. strigosus*, have been used in all crosses. Starting with 'Tulameen' (Figure 1), named in 1989, all cultivars released from the BC programme have the three species in their derivations (Daubeny and Kempler 2003).

Important traits derived from *R. idaeus* are superior fruit qualities including flavour, deep red colour, and a single dominant gene resistance to *Amphorophora agathonica* Hottes, the North American aphid vector of the raspberry mosaic virus (RMV) complex (Daubeny 1996). *R. strigosus* is a source of genes for winter hardiness, resistance to cane diseases and to root rot (Figure 2) caused by *Phytophthora fragariae var. rubi* Wilcox & Duncan and is an alternative source of dominant complementary genes for resistance to *A. agathonica* (Daubeny 1996). *Rubus occidentalis* (Figure 3) is a source of genes for fruit traits, such as firmness, easy harvest, lower levels of susceptibility to rot (caused by *Botrytis cinerea* Pers. ex Fr.), and late ripening (Knight 1993).

Initially the breeding programme was located at the Dominion Experiment Station, Agassiz, which is 120 km east of Vancouver. Now known as a unit of PARC, Agassiz was among the first six experiment stations established by the national government across Canada in the late 19th century. Agassiz has a spectacular location, across the Fraser River from towering Mt. Cheam and other equally imposing peaks. The location is characterized by relatively hot, humid summers and sometimes bitterly cold northeast winds during the winter months, and heavier more poorly drained soils than the Fraser Valley to the west. The valley, once it spreads out, has well-drained sandy loam soils and escapes some of the desiccating winter winds, and the summers are not as hot and humid as those nearer the mountains. It is considered to have some of the best raspberry growing sites, if not the very best, in the world.

I began initial crossing and seedling selection work at Agassiz but soon moved 60 km west to Clearbrook where the federal government had a small substation. It was here that progress was made to select potentially promising raspberry seedlings. Several selections were also made at Agassiz including 'Matsqui', from the cross of 'Sumner', a Washington State University cultivar with some root rot resistance and 'Carnival', a

Photo: Daniel Mosquin

Figure 1. *Rubus* 'Tulameen'

Photo: Hugh Daubeny

Figure 2. A raspberry plant infected with root rot compared to a healthy plant..

Photo: Hugh Daubeny

Figure 3. *Rubus occidentalis*

winter hardy cultivar from the now defunct AFC programme in Ottawa. The cultivar produced fruit of good quality but was considered too pale in colour for the processing market (Daubeny 1980). Moreover, 'Matsqui' did not yield any more than the dominant cultivar of the time, 'Willamette', which had been named in 1943 by the US Department of Agriculture (USDA)-Oregon State University (OSU) programme. During the 1950s, 1960s and into the 1970s, it had become the standard for processing, the main market outlet for raspberries at the time (Daubeny 1980). 'Willamette' is well suited to machine harvesting which was becoming the standard for fruit destined for processing, but it was never considered particularly appealing for the fresh market because of its dark colour and rather acid flavour.

Next came 'Haida', selected from the cross between 'Malling Promise', a widely adapted cultivar grown in the 1940s and 1950s throughout Europe, and 'Creston', a winter hardy cultivar of unknown origin from the Ottawa programme. 'Haida' produces bright non-darkening red fruit, which tends to be difficult to harvest (Daubeny 1980). Plants

are productive, have some resistance to root rot and are winter hardy. But the fruit colour was not particularly desirable for the processing market, which relied on the dark-fruited 'Willamette'. 'Haida' did find a place, albeit small, in the Midwestern US because of its winter hardiness (Daubeny and Anderson 1993). The cultivar has been recognized for its escape from the both the common and the resistance-breaking strains of the pollen borne virus, raspberry bushy dwarf (RBDV) (Daubeny and Anderson 1993; Kempler and Daubeny 2006), and because of this it continues to be used in breeding programmes. 'Haida' is resistant to the common strain of the aphid vector of the potentially damaging RMV. Selecting for aphid resistance in the seedling stage had now become an integral part of the breeding programme.

By 1977, the programme had thousands of seedlings in the field. Rigorous selection identified three worthy of cultivar status; in 1978 these were named 'Chilcotin', 'Nootka' and 'Skeena' (Daubeny 1980). Only 'Chilcotin' was aphid susceptible but it seemed to escape or tolerate the RMV complex. 'Chilcotin' helped revive the fresh market for raspberries in the PNW (Daubeny and Anderson 1993). The cultivar produces bright, non-darkening red fruit with reasonably good shelf life. For a time it had fairly wide acceptance in the PNW and in New Zealand and is still grown for local fresh market sales. It has some root rot resistance, not surprising since the parents are 'Sumner' and 'Newburgh', which like Sumner, is predominantly derived from *R. strigosus* rather than *R. idaeus* (Levesque and Daubeny 1999). 'Chilcotin' seems to escape RBDV (Kempler and Daubeny 2006). The ultimate success of 'Chilcotin' for the fresh market has been limited by lack of a quintessential raspberry flavour.

'Nootka', from the cross of 'Carnival' × 'Willamette' has a high soluble solid content and a good sugar/acid balance. Because of its dark colour and ease of harvest, it seemed an ideal replacement for 'Willamette' (Daubeny 1980). Some 'Nootka' was planted in the early 1980s, but it did not become popular because yields were no higher than those from 'Willamette', which was being replaced by the higher yielding 'Meeker' from Washington State. 'Nootka' is another cultivar that escapes RBDV. It showed lower levels of fruit rot than other

cultivars available at the time. In fact, it became the standard when we selected for lower susceptibility to post-harvest rot. (Daubeny and Pepin 1981). Undoubtedly though, the main claim to fame for 'Nootka' is as a parent of 'Tulameen' (Daubeny and Kempler 2003).

'Skeena' is from the cross of 'Creston' with the Scottish Crop Research Institute (SCRI) selection 6010/52, which is predominantly *R. idaeus* in derivation (Hall and Daubeny 1999). Commercially it was the most successful of the three 1978 releases. It has become the leading cultivar in New Zealand. 'Skeena' is dual purpose, adapted both to processing and fresh markets; however, its fruit colour has never been considered ideal for either, being too light for processing and not quite bright enough for fresh. 'Skeena' is very susceptible to root rot and this has been a limiting factor in acceptance in some raspberry production regions.

'Chilliwack' and 'Comox' were named in 1986 (Daubeny 1987). 'Chilliwack' fruit has bright, non-darkening red colour, relatively low levels of rot, is easy to harvest, has an extended shelf life and an exceptionally fine "raspberry" flavour. It is ideally suited to long distance transport and has been an important cultivar in Chile for the past 15 years supplying fresh raspberries to the northern hemisphere during November and December. It is also widely grown in southeastern Australia where its low chilling requirement is suited to "long-cane" production for season extension in warm environments such as that of northern New South Wales (D. Bardon, Blueberry Farms of Australia, Corindi, NSW, Australia, personal communication).

'Chilliwack' is not a particularly high yielder and this may have limited its acceptance in the PNW. 'Comox', in contrast, is a high yielder (Daubeny 1987). It produces attractive fruit, but is unfortunately a bit difficult to harvest, especially during cool wet weather conditions, and is very susceptible to root rot. Its success has been limited, though it continues to be grown in Tasmania, and to a small extent in Chile and Argentina. 'Skeena' is a parent of both cultivars. The other parent of 'Chilliwack' is a selection from the cross of 'Sumner' × 'Carnival' and of 'Comox', a selection from the cross of 'Creston' × 'Willamette'.

'Algonquin' ('Haida' × 'Canby', an old winter hardy cultivar from the

USDA-OSU programme) was named in 1989 because it was productive and had a bright non-darkening red colour. It had been widely tested in the PNW but was finally deemed unacceptable because of difficulty in harvesting. However, this was not a problem in Ontario where its winter hardiness and compact growth habit, along with good fruit qualities, are appealing. The name 'Algonquin' was chosen to reflect the region of adaptation. 'Algonquin' is the first cultivar to be homozygous for the single dominant gene from *R. idaeus* that confers resistance to the aphid vector of the RMV complex and thus, whenever it is used as a parent, all seedlings are resistant (Daubeny and Anderson 1993).

'Tulameen', named in 1989, was selected from the cross of 'Nootka' × 'Glen Prosen'. The latter is a SCRI cultivar with *R. occidentalis* in its derivation and is notable for firm fruit with thick drupelets. 'Tulameen' is the last of the BC cultivars not subject to Plant Breeders' Rights (PBR), which came into effect in Canada in 1990. It is the first floricane-fruiting red raspberry released in North America that has *R. occidentalis* in its derivation (Daubeny and Kempler 2003). The East Malling Research Station (EMRS) was responsible for introducing the black raspberry into red raspberry breeding programmes in the late 1940s (Knight 1993). This occurred via the old cultivar 'Cumberland,' which is either a direct selection from the wild or one generation removed from it. As many as six to eight generations of backcrossing to the red raspberry have resulted in cultivars with black raspberry traits combined with traditional red raspberry qualities.

'Tulameen' had a remarkably short history before it was named (Daubeny and Kempler 2003). From the cross made in 1980, seedlings selected for aphid resistance were placed into the field in 1982. As early as 1984, the selection BC 80-28-53, which became 'Tulameen', was recognized for outstanding qualities including, large, relatively firm fruit with glossy medium red colour. Fruit was well displayed and easy to harvest. The colour was more attractive than that of either parent and flavour was especially appealing. Harvest began in late June and lasted for approximately six weeks, up to two weeks longer than that of most other cultivars. The plant was vigorous but did not produce excessive primocanes. It was decided to "fast track" the selection.

Propagation of pathogen-free nuclear stock for production of certified plants began immediately. By 1987 there were plants in grower trials and in replicated yield trials, and by the late 1980s plants were sent to various testing sites overseas, in the US and eastern Canada. Favourable performance information was received from the United Kingdom (UK), from various western European countries, from southeastern Australia, Chile, the PNW and elsewhere. It was particularly exciting to learn that the cultivar was being sold under its actual name in many countries.

'Tulameen' seems particularly suited to production under protected structures, including plastic tunnels and greenhouses, allowing for top quality out-of-season fruit (Pitsioudsi et al. 2002; Pritts et al. 1999). Canes have relatively low chilling requirements so are easily forced to bud out and then flower when moved into protected structures. The low chilling requirements are also an advantage when plants are grown in Mediterranean-type climates. It is now profitable for propagators to produce 'Tulameen' canes at higher altitudes or in colder climates to ensure there is adequate chilling before planting in warmer climates.

Of course, 'Tulameen' has some faults (Daubeny and Kempler 2003). The low chilling requirements mean that plants break dormancy early and are vulnerable to winter damage when grown outdoors in many production regions, such as northeastern North America, the Scandinavian countries, Poland and other central or eastern European countries. Damage usually does not occur in the typical winter of the PNW production region. In North America, the UK and Western Europe plants are relatively susceptible to root rot, caused by *P. fragariae* var. *rubi*. Raised beds with polyethylene covering help to reduce the incidence of disease. In Australia plants have some resistance, most likely due to different species or races of the causal organism. Cane diseases can be a problem but are usually controlled by providing better air circulation and avoiding excessive use of nitrogenous fertilizers. Plants are susceptible to RBDV but there is little evidence of infection.

Like most of the cultivars from the programme, 'Tulameen' is susceptible to a resistance-breaking strain of the aphid vector of the RMV complex but neither the aphid nor the virus has been found in the field. The breakdown in the field is a potential problem that has to be carefully monitored.

'Tulameen' has been remarkably successful. It is used extensively in breeding programmes and it is anticipated that some of the progenies will produce cultivars that will be widely grown. It has received outstanding cultivar awards from both the Canadian and the American Societies of Horticultural Science.

The 1995-released 'Qualicum', selected from the cross of 'Glen Moy' (an early ripening SCRI cultivar) × 'Chilliwack', is the first cultivar from the programme to be subject to PBR (Daubeny and Kempler 1995). It produces high yields of large, exceptionally firm fruit that transports well and has relatively low incidence of rot. The cultivar has had some acceptance for fresh market use although its fruit colour is not as bright as that of 'Chilliwack' and is more like that of its 'Glen Moy' parent. The fruit is easy to harvest and is particularly well presented (Back Cover). 'Qualicum' continues to be widely tested and may yet find a significant niche market, perhaps as a fruit for an Individual Quick Freeze (IQF) product. Like the 'Glen Moy' parent it is relatively susceptible to root rot.

'Malahat', the next cultivar was selected from the cross of 'Meeker' with a selection from a seedling population obtained from a SCRI cross involving 'Nootka' and a selection of complex parentage, including the Japanese wine berry, *R. phoenicolasius* Maxim (Kempler and Daubeny 2000). *Rubus phoenicolasius* had been used in the SCRI breeding program as source of resistance to cane beetle, which is a major pest in Scotland but not in the PNW. 'Malahat' produces high yields of large, relatively firm, glossy red fruit suited for the early fresh market. It is a dual-purpose cultivar and later in the season is harvested by machine for processing. 'Malahat' is a successful addition to the cultivars available in the PNW and is attracting interest in other production regions. The diverse origin of the cultivar clearly demonstrates the international nature of modern-day raspberry breeding programmes and the concerted efforts being made to broaden the genetic base of new cultivars.

'Kitsilano', released in 1998, is another cultivar of diverse origin including a selection of an eastern Asiatic species, *Rubus crataegifolius* Bunge, which was used at the EMRS as a source of resistance to cane diseases and to fruit traits such as easy harvest (Knight 1993; Daubeny

1999). 'Kitsilano' is late ripening, with medium sized, very firm fruit. To date, the cultivar has not been grown to any extent, likely because 'Tulameen' fruit, which also ripens relatively late, has a longer season, is larger, brighter and generally more appealing.

'Cowichan', from the cross of 'Newburgh' × 'Qualicum', was released in 2001 (Kempler and Daubeny 2005). Already it seems to have been accepted by the PNW raspberry industry with more than one million plants distributed in 2005. 'Cowichan' could replace 'Meeker' as a leading cultivar throughout the PNW. To date, it has escaped RBDV, which has become rampant in 'Meeker' plantings. The fruit appears equally adapted to processing and to the fresh market. Plants are vigorous and may have some root rot tolerance.

In 2003 two cultivars, 'Chemainus' [('Algonquin' × 'Chilliwack') × 'Tulameen'] and 'Esquimalt' ('Comox' × 'Glen Ample', a relatively new cultivar from SCRI) were named. 'Chemainus' is already attracting a lot of attention. It is suited to processing, including IQF, and fresh market. Its large fruit is dark, glossy and firm (Kempler et al., 2006). 'Esquimalt' is very late ripening with large meaty fruit and is recommended for local fresh market (Kempler and Daubeny 2005). It is expected to be useful in extending the season for the fresh market allowing an overlap with early-ripening primocane fruiting cultivars such as 'Autumn Bliss' and 'Dinkum'.

The latest release from the programme is 'Saanich' [('Algonquin' × 'Chilliwack') × BC selection 80- 28-50, a sib of 'Tulameen')'], another cultivar that is multipurpose and produces high yields of relatively small sized fruit well suited to machine harvest (Kempler and Daubeny 2006). It is being extensively tested throughout the PNW and, as well, in other raspberry production regions.

Some of the advanced selections that are now being evaluated for cultivar status have hitherto unexploited seedlings of *R. strigosus* in their derivations (Daubeny 2003). It is anticipated that several of these will be given cultivar status within the next few years (Kempler and Daubeny 2006). These will broaden the genetic base of *R. strigosus* represented in red raspberry breeding and provide genes for resistance to root rot, other diseases and pests and possibly to the

resistant-breaking strain of the aphid vector of the RMV complex.

The BC programme is indebted to EMRS and SCRI in the UK for introducing *R. occidentalis* and other *Rubus* species into the red raspberry gene pool. Because of these efforts, future cultivars could have as many as seven or eight species in their derivations. Already EMRS has introduced 'Autumn Byrd', a cultivar with genes derived from seven species (Knight 2002). The increased use of these species means higher levels of resistance to diseases, insects and other pests, all of which have favourable connotations to the environment, the producer and the consumer. Resistance to environmental stresses, including those associated with climate changes, are equally important. Furthermore, the introduction of new genes from various species will ensure improvements in fruit quality traits and extension of ripening seasons that will help to meet ever-changing market demands.

Since the species originally introduced into the raspberry gene pool are represented by only one or at the most two or three genotypes, it is exciting to speculate what the results might be if many more genotypes per species were used (Knight 2002). It is absolutely essential all species populations be conserved *in situ* and representative selections taken for evaluation as potential parents. The use of DNA genetic markers to identify important traits will hasten the evaluation procedures and ultimately hasten development of even better adapted cultivars with superior qualities (Daubeny 2002).

Raspberry breeding is an international effort involving both information and germplasm exchanges (Daubeny 2003). It is essential that these exchanges continue to be an integral part of all programmes and not be impeded by privatization that usually restricts exchanges at all levels and ultimately has deleterious effects on both producer and consumer.

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Table1

Origins of cultivar names used in the British Columbia Raspberry Breeding Programme

Algonquin - first nations people in Ontario

Chemainus - town on Vancouver Island - horseshoe shaped bay

Chilcotin - district and river in Cariboo, BC - river people, red or yellow mineralized substance used in dye

Chilliwack - town in Fraser Valley, BC - travel by way of back water or slough

Comox - town on Vancouver Island - place of abundant game or berries

Cowichan - town, river, lake on Vancouver Island - by river or land warmed by sun

Esquimalt - town, part of Victoria - gradually shoaling water

Haida - Haida Gwaii (Queen Charlotte Islands) first nations people famous for largest totem poles

Kitsilano - district of Vancouver Squamish First Nations

Malahat - district on Vancouver Island - place where one gets bait

Matsqui - district in Fraser Valley, BC - easy portage or transport

Nootka - sound on west coast of Vancouver Island - go around or go into harbour

Qualicum - town and bay on Vancouver Island - place of dog salmon

Saanich - district on Vancouver Island - elevated or raised - (as seen through the haze on a summer day)

Skeena - river and district in northern BC - water out of clouds

Tulameen - river in Merritt area of BC, place of much prized red ochre

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