


Production of Berries in Peatlands

by the Peatland Ecology Research Group

Under the supervision of Line Rochefort and Line Lapointe

January 2009

NSERC's Industrial Research Chair in Peatland Management

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Groupe de recherche en écologie des tourbières

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Preface

Berries or small fruits were and have always been a part of humankind's diet. Certain berries, such as blueberries and cranberries, have gained economic importance and have been widely studied and cultivated, while lesser known species remain unsung in terms of cultural practices or the market development.

Nowadays, the potential use of berries as medicinal or nutraceutical food seem pre-eminently great[1]. Because of this interest, areas dedicated to the production of berries are increasing. We predict that demand for berries will increase as scientists discover their potential health benefits[2].

In Quebec, many people agree that production of indigenous berries could revitalize the economy of rural areas and such initiatives are being spearheaded at local levels[2]. Since the peat industry is mainly located in rural areas, it is clear that production of berries following peat extraction could have significant socio-economical advantages for these areas. However, this type of production must be integrated within a well-planned land management plan, combining restoration goals for the ecosystem (ecological restoration of peatland) and reclamation (including berry production) depending on site conditions and the socio-economic context of the area[3].

In addition to the health benefits of berries and their economic value, these plants could be cultivated for their decorative and aesthetic qualities. They could be used as windbreaks or integrated in reclamation projects favouring the return of faunistic biodiversity (notably birds).

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[1] Croisetière, M.-H. 2006. Les petits fruits au secours des régions. Quatre-Temps March 2006 Vol. 30 No. 1. Available online at: http://www.amisjardin.qc.ca/revue/secours_regions_c.htm

[2] Agriculture and Agri-Food Canada (AAC). 2003. Bi-weekly bulletin – Developments in berry production and use, Agriculture and Agri-Food Canada. 6 p. Available online at: http://www.agr.gc.ca/mad-dam/pubs/bi/pdf/bulletin_16_21_2003-12-05_e.pdf

[3] Quinty, F. & L. Rochefort. 2003. Peatland restoration guide, 2nd ed. Canadian Sphagnum Peat Moss Association and New Brunswick Department of Natural Resources and Energy. Quebec, Quebec. 106 pp. Available online at: http://www.peatmoss.com/pm-restguide.php

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Projects on the cultivation of cloudberry in peatlands were also subsidised through a combined effort of the *Fonds québécois de la recherche sur la nature et les technologies* (FQRNT) within the framework of the strategic support for the promotion and consolidation of rural environmental research. Gaétan Chiasson, agronomist for the New Brunswick Department of Agriculture and Aquaculture, as well as the Coastal Zones Research Institute also took part in the project.

A good part of the knowledge presented in this guide is a summary of discussions, scientific symposia and field visits of Commission V of the International Peat Society working group on cloudberry production in peatlands. We especially want to thank: Dr. Kaarre Rapp and colleagues of the Holt Research Center (Tromsö, Norway), Heli Pirinen and colleagues of the ProAgria Kainuu Rural Advisory Centre (Finland), Dr. Kristine Knaess of *Les Buissons* Research Centre (Baie-Comeau, Québec), and Dr. Harri Kokko of the University of Kuopio (Finland).

We would like to extend particular thanks to the producers who took an active part in coordinating field tests by lending equipment, maintaining plantations, providing labour or simply sharing ideas. Special thanks are extended to Juana Elustundo (Fafard & Frères ltée) and Annie Bourassa (Premier Horticulture ltée).

Introduction

This guide presents current knowledge of berry production in peatlands following peat extraction. Our goal is to collect relevant information on a variety of indigenous species that present viable cultivation potential in peatlands in order to equip producers who want to invest in berry production.

Many berries possess strong potential for cultivation on cutover peatlands after peat extraction, notably, species from the Ericaceae and Rosaceae families. Species presented in this guide are taxons indigenous to North America and most of them are found in peatlands or around their perimeter.

The guide is divided into chapters that offer information on the species discussed. You can find, according to each taxon, summary information on the biology of the species and the most promising cultural practices based on the most recent findings or according to literature reviewing what has been done elsewhere, as well as a list of the most relevant resources (key informants, Web sites, etc.). In brief, this is what is presented:

Chapter 1 – The cloudberry: This chapter is, in fact, an update of an initial report published in 2005 by the Peatland Ecology Research Group (PERG). We present the findings of research conducted on the cloudberry in Eastern Canada by teams led by professors Line Lapointe and Line Rochefort from the *Université Laval.* Findings from Fennoscandia are also included. We not only discuss cloudberry cultivation on cutover peatlands (after peat extraction), but we also discuss its cultivation on natural peatlands. This chapter is longer than the others because this particular berry was the subject of research of three masters and two doctoral students from the Plant Sciences and Biology departments at *Université Laval.*

Chapter 2 – The black chokeberry: This chapter assesses the results of different research projects on cutover peatlands headed by Line Rochefort's team since 2000. We also take a look at findings in other environments.

Chapter 3 – The serviceberry: This chapter summarizes the findings of a trial on the saskatoonberry and the existing literature on the subject. We also raise some ideas for future trials with new species, like the Barthram's serviceberry, which is probably better adapted to peatlands.

Chapter 4 – The elderberry: As in the previous chapter, we review existing knowledge acquired following a trial on a cutover peatland. Research leads are suggested for future trials.

Chapter 5 – The cranberry and Chapter 6 – The blueberry: Cranberry and blueberry production is well established in Eastern Canada. Projects undertaken by the PERG have not focused on these two species due to existing expertise at local or provincial levels. We offer a rather brief summary of their cultivation in peatlands and provide a current list of the most relevant resources (Resource persons, Internet sites, etc.).

Chapter 7 – The other berries: This last chapter addresses a few species that are not widely known but garner some interest for cultivation. It focuses on the lingonberry, the crowberry, the black huckleberry, the strawberry and the brambles.

Photo: Mireille Bellemare

Chapter 1:

The cloudberry

by

Mireille Bellemare,
Guillaume Théroux Rancourt
Line Lapointe and
Line Rochefort

Photo: Mireille Bellemare

1.1. Introduction

Cloudberry (*Rubus chamaemorus* L.) is a plant found in northern countries of the Northern hemisphere. Its fruit, which is not well known in Canada, was used by First Nations people for its medicinal proprieties (Small and Catling 2000). Because of its high vitamin C content, inhabitants of these northern regions would eat it to fight scurvy (Nilsen 2005). Cloudberry has been picked in Fennoscandia for centuries, where this fruit is highly sought-after and widely commercialised, but it's now more difficult to find pickers because they are older and their youth is not interested in this demanding and low paying task (Saastamoinen 1998). To overcome this problem, many have been trying to develop the commercial cultivation of cloudberry.

The first cultivation trials took place in Norway in the 1930's (Mäkinen and Oikarinen 1974), but it took another twenty years for larger scale trials to begin in this country (Østgård 1964). Nevertheless, it is after 1980 that research intensified in Finland (Kortesharju 1982, 1986) as well as in Norway (Rapp 1992). The Norwegian trials recently led to the publication of a cloudberry growers guide (Rapp 2004a). Two female cultivars and two male cultivars were also officially recognized. Presently, cultivation trials are ongoing at a Norwegian cutover peatland (I. Martinussen, Bioforsk Holt, Norway, pers. comm.), in fields and greenhouses in Finland (H. Pirinen, Pro Agria Kainuu, Finland, pers. comm.) and in greenhouses in southern Sweden (Wendell 2005).

In Canada, few cultivation trials were attempted other than those attempted on the Côte-Nord in Quebec in 2004 by the Peatland Ecology Research Group (PERG) and researchers from the *Centre de recherche Les Buissons.* However, knowledge of the species' biology has improved over the last 20 years (Dumas and Maillette 1987, van Bochove 1987, Jean and Lapointe 2001).

This chapter presents current knowledge on the cultural practices of cloudberry in peatlands following undertakings carried out in Eastern Canada. It also includes information collected during a research mission to Fennoscandia financed by the NSERC's International Opportunity Fund (2003), led by professors Line Lapointe and Line Rochefort along with Kristine Naess (Centre Les Buissons) and within the framework of L. Lapointe's sabbatical year in Sweden (2004 to 2005). Information gathered by Mr. Guillaume Théroux Rancourt during his internship in Finland under the supervision of Mrs. Heli Pirinen, project manager for cloudberry cultivation in the Kainuu region (2004), and during his work as a research professional at the MTT Agrofood Research Finland Experimental Station in Sotkamo (2006), is included in this chapter. Finally, it provides a review of literature and the results of recently conducted research in Quebec and Fennoscandia.

1.2. Species biology

1.2.1. Names

Cloudberry belongs to the Rosaceae family. Its scientific name, *Rubus chamaemorus* L., is derived from the Greek word *chamae*, meaning small or "on the ground" and from the genus *morus*, which means white mulberry (Small and Catling 2000). Its lesser-known French name is Ronce petit-mûrier (Marie-Victorin 1995). Its vernacular name – chicouté – is a Montagnais word meaning "fire" and was named as such because of its red colour before it achieves maturity (Marie-Victorin 1995). Inhabitants of Eastern Canada refer to cloudberry under different common French names such as "plaquebière", "blackbière", "mûre blanche", "margot", "ronce des tourbières" and "mûre des marais". In English, the fruit is sometimes called bakeapple, but this designation is mostly used in Newfoundland and Labrador. Natives from Alaska sometimes erroneously name it salmonberry because of its resemblance to salmon eggs (Small and Catling 2000).

1.2.2. Distribution and habitat

Cloudberry is a circumpolar boreal plant which can be found in the Northern hemisphere in Siberia, in Fennoscandia, in Canada and in the United States (mostly in Alaska). It can be found from between latitude 78°30' N in Svalbard Norway to latitude 44° N in Maine and New Hampshire in the United States (Resvoll 1929). Its most common flourishing habitat is ombrotrophic peatland, often in the presence of *Sphagnum fuscum* (Lohi 1974, Mäkinen and Oikarinen 1974). We can also find it on mineral soils with a good layer of humus (Rapp 2004a). Figure 1.1 represents a map of the species' distribution in Quebec and in Labrador, based on cloudberry specimens preserved at the Louis-Marie herbarium of *Université Laval* in Quebec.

1.2.3. Plant characteristics

It is a shrubby species because of its woody rhizome which produces annual herbaceous aerial stems. Cloudberry reproduces mainly vegetatively (clonal growth). It is dioecious, meaning that only the female plants can produce fruit (Dumas and Maillette 1987).

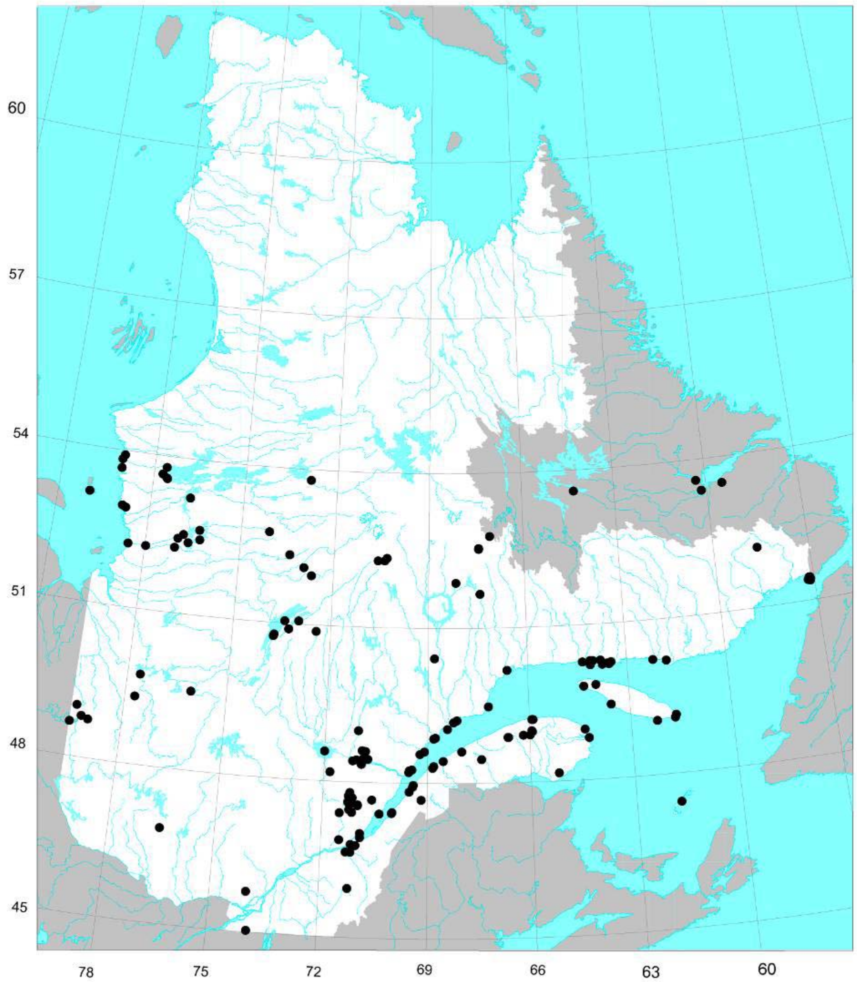

Figure 1.1: Distribution map of cloudberry in Quebec and Labrador based on coordinates from harvested cloudberry specimens which are preserved at the Louis-Marie herbarium of *Université Laval* in Quebec (prepared by Kim Damboise, Louis-Marie Herbarium).

1.2.3.1. Vegetative parts

<u>*Rhizomes and roots*</u>

Cloudberry rhizomes are important organs for vegetative reproduction and to accumulate reserves. They branch and develop at different depths parallel to the ground surface (Resvoll 1929; Figure 1.2). They can be found regularly from the surface (up to 25 cm in depth; Wallén 1986) down to the lower limit of the decomposed moss (Metsävainio 1931). They are mostly observed just above the ground water level in ombrotrophic peatlands (G. Théroux Rancourt, pers. obs.). Rhizomes of female clones have an average length of 9.7 m (Jean and Lapointe 2001). Annual growth can exceed 50 cm in very favourable habitats (Mäkinen and Oikarinen 1974), but since clones intertwine, more than 200 meters of rhizomes have been measured over one square meter of peatland (Kokko *et al.* 2004). Rhizomes possess dormant buds that are spread out every few centimetres or decimetres, and each one has the potential to produce a new rhizome branch or aerial root (Mäkinen and Oikarinen 1974).

Figure 1.2: Cloudberry rhizome rooted in a pot which shows good root growth and the presence of new rhizomes (white, in the middle). Photo: Jin Zhou.

Rhizomes contain sugar reserves that represent approximately 23% of their dry biomass (Jean and Lapointe 2001). The accumulation of carbon reserves in rhizomes is rapid at the start of the growth season and diminishes when the growth of the fruit begins. Afterwards, the rhizome accumulates new reserves.

Roots along the rhizome are not very plentiful (Taylor 1971). They branch out according to their growth habitat: in a humid environment, the rhizome possesses only a few roots (Resvoll 1929, Jean and Lapointe 2001). Roots can be observed to grow more deeply than the rhizomes, as deep as the ground water level, because of the presence of aerenchymas (Metsävainio 1931, Wallén 1986). The average depth observed was 47 cm with minimum and maximum of 15 and 60 cm. Unpublished trial results conducted in Norway and Quebec demonstrate how little effect auxins have on root growth (I. Martinussen, Bioforsk Holt, Norway, pers. comm., and G. Théroux Rancourt, pers. obs.).

Leaves

Each ramet possesses between one to three simple leaves in alternate arrangement (Figure 1.3). They are reniforme, each possessing between three to seven rounded lobes (Marie-Victorin 1995). The size of the leaves varies between 2 to 5 cm in lenght and 3 to 7 cm in width (Taylor 1971). In a natural habitat, the foliar surface is roughly 7 cm^2 but may vary depending on the environment, leaves in semi-closed forest being larger than those in open peatlands (Lohi 1974).

Figure 1.3: Cloudberry leaf. Photo: Guillaume Théroux Rancourt.

1.2.3.2. Flowers

The flowers, which are white and solitary, are found at the tip of the stem. They generally have the five sepals (Taylor 1971) and the five petals typical of the Rosaceae family (Figure 1.4). Their size vary according to their habitat; they are bigger in shady environments which are sheltered from the wind than those in sunny and open environments (Resvoll 1929). The number of stamens varies from 25 to 120, whereas the number of pistils varies from 3 to 40. Cloudberry is dioecious, but flowers from each gender have rudimentary organs of the other gender. Each flower opens for two to three days, and the flowering period of the entire population lasts about two weeks (Ågren 1987b). The floral bud is formed during the year preceding flowering.

Figure 1.4: Male (right) and female (left) cloudberry flowers. Photo: Jin Zhou.

Hermaphrodite specimens have been observed, but they are rare and sporadic (Gustafsson and Kortesharju 1996; M. Bellemare, pers. obs.). There are many levels of hermaphrodism depending on the level of stamenoids development (Figure 1.5). Over the past few years, a stable hermaphrodite clone has been propagated in Finland, and its commercial distribution has started under the name Nyby, the village from which the clone originates (M. Uosukainen 2006, MTT Agrifood Research Finland, Laukaa station, Finland, pers. comm.). Many other trials have been conducted in order to propagate hermaphrodite clones, but they have reverted to being male clones after a few growing seasons, which does not seem to be the case for the Nyby cultivar.

Figure 1.5: Hermaphrodite cloudberry flowers. Photos: A) Guillaume Théroux Rancourt, B) Caroline Mercier.

1.2.3.3. Fruits

<u>*Fruits morphology and maturation*</u>

The spherical cloudberry fruit is a polydrupe: each carpel fertilized on the receptacle forms a drupelet. One fruit can have from 1 to 31 drupelets in natural environment (Jean 1998). Fruits observed on the Côte-Nord, in Quebec, average less than 5 drupelets per fruit (Bellemare 2007). Cloudberry seeds are voluminous. This feature is put to profit in Finland where they extract oil from cloudberry seeds to manufacture cosmetics (ex.: Lumene products). The fruits are not only well-liked by humans but by birds, foxes and bears too (Resvoll 1929).

The cloudberry fruit changes in appearance throughout its maturation: it evolves from a bright red and opaque colour to becoming orange, amber and translucent when it achieves maturity (Beaulieu *et al.* 2001; Figure 1.6). It has been noted that, in open peatlands, fruits that mature earlier contain more seeds and produce a higher total seed mass than fruits that mature later (Ågren 1989).

The speed at which fruit matures is most likely affected by temperature (Kortesharju 1993). In fact, for each rise of 1 °C, there is a 1.7 day reduction in the duration of the fruit maturation period. Furthermore, an increase in the number of drupelets reduces the number of degree-days necessary for the fruit to achieve maturity. However, this outcome vanishes when fruits have more than 8 drupelets. This means that a fruit possessing 10 drupelets takes 80 to a 100 fewer degree/days to achieve maturity as opposed to a fruit possessing only one druplet.

A

B

Figure 1.6: Different stages of maturity of cloudberry fruits, from closed sepals around the fruit (A) to the mature fruit (B). Photos: A) Mireille Bellemare, B) Heli Pirinen.

Mass of the fruits varies greatly in nature, but they usually weigh between 1 and 2 g. A Finnish contest to find fruits with superior masses for genetic selection produced a winning fruit weighing 6.5 g (Kokko *et al.* 2000). The mass of the seeds was positively correlated to the mass of the fruits. However, a few of these fruits had fewer seeds and therefore had more pulp. Some 5.5 g fruits were produced in greenhouses with the fruits collected from the contest. Furthermore, three red fruit genotypes, in addition to one white fruit genotype, were harvested in nature. In Norway, a blue genotype was also observed (K. Rapp 2004, Bioforsk Holt, Norway, pers. comm.). Fruits harvested in natural peatlands in the Côte-Nord region of Quebec had an average weight of less than 1 g (Jean and Lapointe 2001, Bellemare 2007).

According to a study conducted in greenhouses, the use of gibberellins (GA_3; between 2.5 µg and 10 µg per open flower) can lead to the development of parthenocarpic fruits (in other words, fruits that grow without fertilization as a result of the use of chemical agents or natural vegetal or synthetic hormones; Gustafsson and Kortesharju 1996). These fruits have an average of 20 drupelets. Seeds produced from parthenocarpic fruits did not have embryos: their seed mass was low. The use of auxins did not prompt parthenocarpic fruits to develop.

Nutritional composition of the fruits

Generally, berries are rich in antioxidants and phenolic compounds. Moreover, they are a good source of fibre. Their carbohydrate content is lower than the majority of other fruits. Small Nordic fruits have low sodium contents but high levels of potassium, both elements playing a role in blood pressure regulation (R. Törrönen 2004, Kuopio University, Finland, pers. comm.). Cloudberry contains anthocyanins; the red genotype possesses roughly 85 times more anthocyanins than the yellow fruit which we usually encounter (see Appendix 1, Table 1). However, it contains a higher level of ellagitannins, molecules with anti-mutagen and anti-carcinogenic properties (Mylnikov *et al.* 2005). Cloudberry contains 6.6 mg/kg of flavonoids, a phenolic compound (Hakkinen *et al.* 1999). Finally, cloudberry displays strong anti-microbial activity, notably countering intestinal pathogens such as *Staphylococcus* and *Salmonella* (Rauha *et al.* 2000, Puupponen-Pimia *et al.* 2001, 2005).

The average quantity of dry material contained in cloudberry fruits is approximately 13.6%, while its sugar content is 5.7% (Røthe *et al.* 2000). Between 50 and 150 mg of ascorbic acid (vitamin C) and approximately 50 mg of benzoic acid have been reported per 100 g of fruit

(Small and Catling 2000). Benzoic acid is a good preservation agent; it allows cloudberry to stay intact for several days after harvest. Aromatic compounds are also present in the cloudberry fruit which gives it its unique and pleasant aroma (Honkanen and Pyysalo 1976, Small and Catling 2000). These compounds amount to approximately 53% of the essential oils extracted from cloudberry juice.

1.2.4. Phenologic stages

Cloudberry is one of the first vascular species to bloom in the spring in ombrotrophic peatlands. Cloudberry phenologic stages have been described by Beaulieu *et al.* (2001; Table 1.1) and also by Yudina (1993). In Moyenne-Côte-Nord, the flowering period starts at the beginning of June and ends at the beginning of July, each flower being open for only a few days (Jean 1998). Fruits achieve maturity around the third week of July (Beaulieu *et al.* 2001). Phenology occurs a little earlier in Haute-Côte-Nord, in years of early snow melt. Flowering begins near mid-May when the temperature is mild and fruit maturation takes a little over 35 days (Gauci, in preparation). Finally, in Basse-Côte-Nord, the growth season for cloudberries lasts between 3 to 4 months (van Bochove 1987). The first male flowers appear in mid-June while the female flowers open approximately a week later. Fruits achieve maturity around August 10^{th}.

1.2.5. Mycorrhizas

Results of mycorrhizal analysis are rather mixed. Research targeting mycorrhizas in cloudberries led to limited positive identification. A Canadian study reports the presence of vesicular-arbuscular mycorrhizas among cloudberry specimens (Thormann *et al.* 1999). However, an English study did not observe mycorrhizas in a natural environment (Taylor 1989), same observation as a more recent Canadian study conducted on cloudberry specimens from seven peatlands located in the Côte-Nord region (Y. Dalpé 2005, Agriculture Canada, pers. comm.).

Inoculation trials of cloudberry plants with mycorrhizas showed that cloudberry can be infected by *Glomus mosseae* BEG29 fungus, a commercial species from Finland (G. Théroux Rancourt and collaborators, 2006, MTT Agrifood Research Finland, unpublished data). However, only 5% of the plants were infected and the infection rate was 1% in each plant. Cloudberry can thus be infected, but the success rate is very low and is most likely due to the presence of mineral particles in the mix of mycorrhizas, peat being an unfavourable environment for the growth of arbuscular mycorrhyzas (M. Vestberg 2006, MTT Agriffod Research Finland, Laukka station, Finland, pers. comm.). Therefore, we expect that the mycorrhization process will show little activity in cloudberries and provides little nutritional value to the plant.

Table 1.1: The description of the cloudeberry's phenologic stages (adapted from Beaulieu *et al.* 2001).

Stage	Description
Dormancy	The dormant terminal bud, protected by brown scales, will form the aerial stem the following year.
Budbreak	The first leaf primordium unfolds and pushes aside the scales.
Flowering bud	The flowering bud appears. The flowering bud develops and expands.
Beginning of flowering	The flowering bud opens. Petals develop and expand.
Full flowering	Male and female flowers are open. Entomophilous pollination takes place.
Calyx	Petals fall after fertilization. Sepals close on the gynaeceum.
Fruit setting	The fruit grows. Fruit growth opens the sepals.
Beginning of the red fruit	The fruit color changes rapidly from green to red when exposed to light. As the fruit matures, sepals continue to open.
Beginning of the orange fruit	The fruit changes from red to orange and losses its firmness; sepals completely roll back and fade. Once it turns orange, the fruit becomes translucent.
Seed	The drupelets pericarp and stone containing the seed fall on the ground.

1.2.6. Factors affecting yield

1.2.6.1. Limitation of resources

One of the factors explaining low and variable cloudberry yields (see section 1.3. Cultivation in natural populations) is the species' vegetative reproduction process. In fact, approximately 95% of its biomass is allocated to underground organs and only 0.05% to sexual reproduction, the remainder being subdivided between the aerial root and the leaves (Dumas and Maillette 1987). Female clones produce an average of 6.2 ramets of which 1.7 bear a flower (Jean and Lapointe 2001). In addition to producing few flowers, many fruits die prematurely during development. One explanation for the high rate of fruit abortion lies in the limited carbohydrate storage capacity of the cloudberry rhizome. Carbohydrates represent roughly 23% of the rhizome's dry biomass (Jean and Lapointe 2001). This is low compared to the fruit's need for carbohydrates; a longer rhizome would diminish the rate of fruit abortion because more reserves would be available.

The availability of nutrients is low in peatlands. Thus both carbon and nutriments could be limiting fruit production in cloudberry. However, results obtained so far suggest that the most limiting factor is carbon rather than nutrients. Many phenomena contribute to this lack of carbon: competition between developing leaves and fruits at the beginning of the season, low carbon reserves in rhizomes at the beginning of the growth season, potential competition between developing rhizomes and fruit, as well as some mineral deficiencies which limit carbon movements inside the plant (Gauci, in preparation).

1.2.6.2. Frost

Frost is the most frequent limitative factor for cloudberry yields (Kortesharju 1988). It accounts for 38% of the abundance variation index of cloudberry in natural environments during flowering (Wallenius 1999). This is due to the fact that bud burst occurs during a period where the risk of frost is high (van Bochove 1987, Ågren 1988). Frost events during flowering can greatly limit fruit production. Female flowers are more sensitive to low temperatures, with temperatures of 2 ºC being lethal to them, whereas male flowers can survive to temperatures as low as -4 ºC (van Bochove 1987, Yudina 1993). However, consecutive nights under 0 ºC are fatal to both genders. Frost resistance increases during fruit maturation, and fruits can endure temperatures as low as -3 or -4 ºC (Kortesharju 1995). Different populations of cloudberries were analyzed relatively to the occurrence of frost in their environment (Ågren 1988). Variations in the proportion of floral buds that flower and set fruit can largely be explained by the presence of frost during flowering and fruiting among populations frequently exposed to frost. Flowering and fruit production is generally low among these populations, except for certain exceptional years where production increases greatly. However, some female flowers die prematurely without signs of physical damage among protected populations. Cloudberry produces more flower buds to take advantage of frost-free years. Supernumerary flowers can also control negative effects of herbivores and eliminate certain inferior genotypes.

1.2.6.3. Other factors

Other meteorological variables, such as the number of days of heavy rain, accumulation of precipitation, etc., can have limited effects on the yield during both flowering and fruit maturation (Wallenius 1999). Rather, the yield appears to be influenced by the many factors that interact with each other. Nevertheless, a heavy and intense rainfall during flowering period greatly affects the yield by irreversibly damaging flowers (Brown 2005; M. Bellemare, pers. obs.).

Deficient pollination, caused by strong winds, precipitations or a variation in pollen availability, directly affects cloudberry yield (Ågren *et al.* 1986). Furthermore, the activity of pollinators is curbed by cold temperatures, a common phenomenon during the flowering period (Yudina 1993). The best conditions for pollination are temperatures above 10 °C and a lack of precipitation (Rapp 2004a). However, temperatures over 30 °C can also affect pollination (Hippa *et al.* 1981). Poor pollination reduces fruit mass: fruits that weight less than 0.5 g were observed following mediocre pollination conditions. When conditions are favourable and pollination is efficient, the fruit mass can be three or four times higher (Kortesharju 1988).

Herbivores and fungal parasitism also affect yield (Ågren 1987a, b, 1988). In Finland, a very hot summer can prompt the appearance of *Galerucella nymphaeae* and *G. sagittariae*, insects that feed on cloudberry leaves (Nokkala and Nokkala 1998, Wallenius 1999). Leaves from male individuals are more affected by herbivores and pathogens than leaves from female individuals. The reason for this preference is still unknown (Ågren 1987a).

1.3. Cultivation in natural populations

It is interesting to take a closer look at suggested cultivation methods for cloudberry in natural peatlands because it already flourishes in this environment. The objective of these methods is to increase fruit yield and reduce inter-annual variability. In natural habitats, fruit yield is generally low and varies greatly from one site to another as well as from year to year (see Table 1.2) when compared to other wild berries. On a relatively productive peatland, the average fruit yield is 300 kg/ha. However, it can vary between 0 and 3 500 kg/ha, depending on the environment and the year. It is a far cry from the 6 725 kg/ha yield of wild blueberries produced on unprepared area in Maine USA (Yarborough 1998). In the province of Quebec, the average yield of wild blueberries on blueberry fields was 1 034 kg/ha from 1998 to 2003, with a general tendency toward yield increase (MAPAQ 2005).

Table 1.2: Cloudberry fruit yield (kg/ha) in natural habitats (from Théroux Rancourt 2007).

	Yield (kg/ha)		Reference
	Average	Maximal	
Natural sites			
Finland			
Undrained *Sphagnum fuscum* peatland	52.9	160	Kortesharju (1988)
Peatlands drained with ericaceous shrubs and Norway pines	0.1	0.3	4-year average
Cottongrass and Scots pine peatland	27.5		Jääskeläinen (1981)
Ericaceous shrubs and Scots pine peatland	31.6		Data over 1 year
Inari, Riutulan tie (per 1 m^2)	3 960		Mäkinen (1972)
Inari, Riutulan tie (per 1 ha)	12		
Russia			
Open peatland		463	Yudina (1993)
Canada (North of Quebec)			
Peatland	4.5		Dumas and Maillette (1987)
Moss community	6.5		Data over 1 year
Spruce stand	3.4		
Herbaceous lichen colony	10.9		
Shrubby lichen colony	1.7		
Canada (Basse-Côte-Nord, Quebec)			
Lac aux Bouleaux peatland	5.75		van Bochove (1987) 2-year average

Obviously, it is important to evaluate the quality of the site before starting any land management work. An initial density of at least 10 female flowers per m^2 is recommended in order for it to be viable (Rapp 2004a). The two techniques used in natural habitats are: 1) substrate fertilization and 2) tillage combined with substrate fertilization.

1.3.1. Fertilization method

A prerequisite for using this method is a peatland that is sufficiently dry and drained to insure that the fertilizer does not come in contact with ground-water (Rapp 2004a). To apply fertilizer, holes ranging from 10 to 20 cm deep are dug a meter from each other with a sharp stick. Then, 40 to 50 g of a 14-14-19 fertilizer is placed into each hole. Fertilizer application can be done in the spring before flowering or in August-September, after harvest, every ten years (Rapp 2004a). This gap between fertilizations seems too long to us and should be re-evaluated.

1.3.2. Fertilization and cultivation methods

Tillage before fertilization, such as sectioning of rhizomes with a disc harrow, can increase the density of the plants (Rapp 2004a). Field trials in Moyenne-Côte-Nord have showed that it takes three years before seeing an increase in the amount of fruit produced (Bellemare *et al.* submitted ; Figure 1.7). Combining sectioning of rhizomes and fertilization did have a positive effect on cloudberry vegetative productivity that can be noted by the higher density of ramets (Figure 1.8), leaves and flowers (an increase of 10 flowers per m^2) in the treated parcels. During this trial, sectioning was carried out in the spring, when the ground was still frozen, by making 30 cm deep cuts with a chainsaw, spaced a meter apart. After sectioning, the above-mentioned fertilization process was carried out.

On larger scale, bigger machinery can also be used. In areas where the soil is dry enough to withstand the weight of a tractor and an agricultural tool, a plough equipped with 14 to 16 inch ploughshares to create 15 cm deep furrows every meter can be used (Rapp 2004a). Thereafter, surface tillage (10 to 15 cm) has to be done using a cultivator to give the media sufficient airing. The use of a ditch cleaner is required on very humid peatlands. The water level in drainage ditches must be kept between 30 to 50 cm, and they must be dug perpendicularly to the peatland's slope. A unique recommendation for depth and distance between ditches cannot be universally applied because of the differences between sites.

New studies on natural peatlands should be carried out in order to increase the profitability of this type of cultivation. It would be interesting to try other fertilization methods in order to target specific increases for fruit yields. The addition of boron, which could stimulate pollen vitality, leading to larger yields among many species, could be an interesting option to explore (Wojcik 2005a, b). It could also be viable to combine the selection and fertilization processes, which have already been tested, with a trial featuring the control of competitive plants and more intense tillage.

Figure 1.7: Follow-up on cloudberry density in a natural peatland, two years after rhizome sectioning and fertilization treatment (Pointe-Lebel, Côte-Nord, Quebec). Photo: Guillaume Théroux Rancourt.

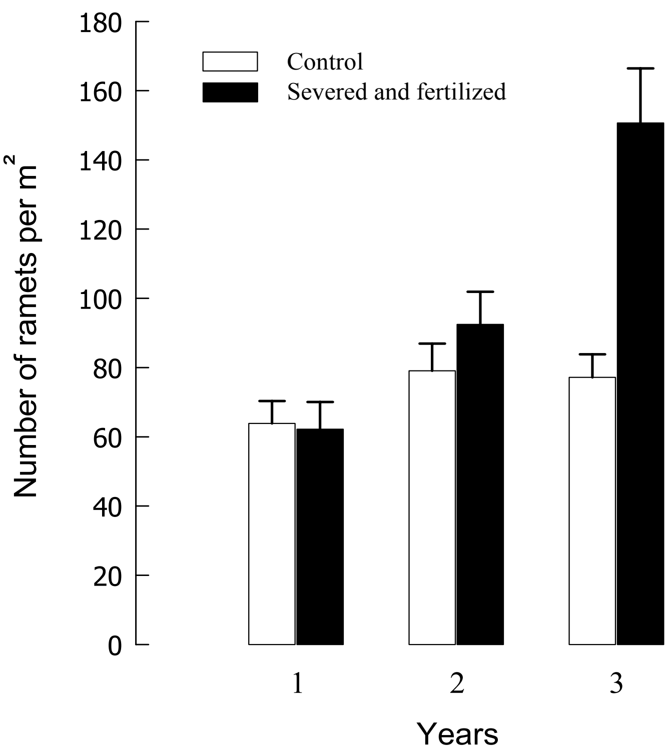

Figure 1.8: Number of ramets per m² in June according to the treatment administered (average ± standard error). Figure drawn from Bellemare (2007).

1.4. Cultural practices

When female cloudberry plants are lacking, we can resort to a third cultivation method which includes tillage, the planting of productive cultivars and fertilization (Rapp 2004a). This also applies to the planting of cloudberries in cutover peatlands (after peat extraction), from a reclamation perspective. This section will focus on this particular situation and will present the different steps to achieve it.

1.4.1. Plants

Since cloudberry is not normally found on cutover peatlands (after peat extraction), it is important to use plants adapted to the proposed environment while presenting interesting agronomical characteristics. This section will describe the choice of cultivars or clones for plantation, their spreading and their storage.

1.4.1.1. Choice of cultivars

In order to obtain plants which possess the best agronomical characteristics, cloudberry cultivars were developed in Norway towards the end of the 1980's (Rapp 1989). According to Rapp and Martinussen (2002), the most important criteria for selecting clones are:

- the size of the fruits (number of pistils per flower) for females and flower size (number of stamens per flower) for males;
- the number of flowers per m^2;
- the speed of growth (number of shoots per m^2, the first and second year).

Using these criteria, researchers were able to isolate the most efficient male and female clones among the ten or so harvested. Two male cultivars, Apollen and Apolto, and two female cultivars, Fjordgull and Fjellgull, were selected this way (Rapp and Martinussen 2002). The most interesting cultivars for us are the females, since they are the ones who produce fruits. However, a good male cultivar is necessary to insure that there is enough pollen for pollination (Rapp 2004b).

These cultivars are well-adapted to their local conditions; the Fjordgull cultivar is from an island, whereas Fjellgull is from a mountainous region (Rapp 1991). However, after a few years of field trials, it has become obvious that the Fjellgull cultivar is much less efficient than the Fjordgull cultivar (Rapp and Martinussen 2002). The Fjordgull's superiority was also observed in Quebec, where it achieved the best survival rate on cutover peatland. The Fjellgull achieved results similar to local clones from Quebec and New Brunswick (Théroux Rancourt 2007).

The fact that one cultivar performs better than the others has prompted researchers to develop more regional female cultivars, hence producing cultivars that are well adapted to different local conditions, as well as increasing the diversity of cultivars planted on a same site. Currently, selections are on-going in Quebec (K. Naess, *Les Buissons* Research Center), in Finland (K. Hoppula, MTT Agrifood Research Finland, Sotkamo station) and in Norvway (I. Martinussen, Bioforsk Holt). Furthermore, breeders want to add more selection criteria, such as pollination capacity, which, in other words, will improve the flower's ability to receive pollen and become fertilized (K. Rapp 2004, Bioforsk Holt, Norway, pers. comm.).

1.4.1.2. Plant and rhizome production

Two types of transplants are found in Norway and Finland: ball plants (multicells; Figure 1.9A) and rhizome fragments. Ball plants are more expensive to produce, but allow for better implantation while saving a year of growth in the field, thus reducing the time interval before the first harvest of fruit.

Vegetative propagation of rhizomes normally occurs in large flowerbeds which are roughly 50 cm in depth. A heating system can be installed under these flowerbeds in order to allow them to thaw faster in the spring. Maximal rhizome production occurs along the side of the flowerbed walls where aeration is better. To improve aeration in the flowerbeds, drainage tiles, inner wooden walls or smaller perforated bins have been added (D. Eggen, Eggen Gartneri, Norway, pers. comm. and G. Théroux Rancourt, 2006, MTT Agrifood Research Finland, Sotkamo station, ongoing experiment).

A B

Figure 1.9: Cloudberry plants in multicells (A) and production of cloudberry rhizomes (B). Photos: Guillaume Théroux Rancourt.

Rhizomes production is usually done in tunnels (Figure 1.9B). They contain three cultivation zones, each representing one production year for each cultivar. Planting begins in the spring when the ground thaws (end of May, beginning of June). Plants are usually fertilized from the first year using a nutrient solution or a slow-acting fertilizer. The use of a 400 g/100 L slow-acting fertilizer (13-13-13) appears as the ideal fertilizer for the growth of plants, at least, according to tests conducted so far (0 to 800 g/100 L; Bellemare 2007). Norwegian recommendations call for 200 g of 14-14-19 fertilizer per 100 L of peat used (Rapp 2004a).

One of the problems that can occur during rhizome production is the development of a dense moss cover. This mat can reduce the amount of air which penetrates the soil substrate, affecting cloudberry. The moss cover can be reduced by applying fertilizers to the substrates instead of using aerial irrigation. This has not yet been tested, but a reduction of moss cover was observed when the fertilizer was mixed with the substrates during experiments conducted in greenhouses (M. Bellemare, pers. obs.).

During the winter, production bins are covered with a geotextile after the plastic covering the tunnel has been removed. Snow offers an efficient protection against freezing damage.

During the month of October of the third year, peat substrate is cut in blocs using a long knife. The rhizomes are taken out of the peat and are put in cold storage between two layers of peat. Some rhizomes are planted in pots and placed in cold storage. The remaining rhizomes are placed in bags and covered with peat before being placed in cold storage. After three years, one may obtain as many 2 000 rhizome segments per m^2.

It is not until February or the beginning of March that rhizomes are cut. Selected rhizomes are cut to a length of at least 15 cm because in 99% of cases, there is at least one dormant bud on the rhizome. The optimal length is 22.5 cm in order to insure best survival and growth rates for the rhizomes, at least, according to studies conducted in greenhouses (Rapp *et al.* 2000). Similar results were obtained in Quebec, where local rhizome clones of 20 to 25 cm had a better survival rate than those that were 15 cm long (Bellemare 2007).

1.4.1.3. Rhizome storage and preservation

In Norway, rhizomes are stored on damp paper and placed in non-airtight bags. Afterwards, they are placed between layers of peat. The rhizomes can remain in this state for a few months. The rhizomes can also be stored in damp peat placed inside plastic bins.

No preservation temperature is currently recommended, but we notice a loss in the rhizome's vitality during the winter storage. If long-term storage is the issue (ex.: all of autumn and winter), storage between -1 and -2 °C could be most viable, insomuch as the rhizomes are well protected against winter drying. This method is recommended in Norway. Storage between +2 and +4 °C is acceptable for short periods of time (a few weeks) because rhizomes will eventually sprout at these temperatures.

1.4.2. Planting

1.4.2.1. Site selection and preparation

The first steps towards planting are the selection of an appropriate cultivation site and its preparation. According to Norwegian growers guide (Rapp 2004a), the conditions of an adequate site are:

- pH of 3.5 to 4.5;
- fibric peat, between H2 and H4 on the von Post scale, which insures adequate aeration of the rhizomes;
- adequate availability of water.

However, these recommendations do not take into account the physical and hydrological attributes of the peat, which can vary within the same level of peat decomposition, and which varies considerably on cutover peatlands (Price 1997, Brandyk *et al.* 2002, Price *et al.* 2005).

A recent study conducted in Quebec attempted to assess the impact of physical and hydrological attributes of substrates on the implantation of cloudberry on cutover peatland (Théroux Rancourt 2007). This study showed that physical attributes tend to influence growth of cloudberry after a few years, although no effects can be observed in the short-term (first two years of growth). Cloudberry growth on a site with high bulk density of the soil (weight of dry peat per volume in g/cm^3) stagnates after three years of cultivation. Soils with high bulk density have higher water holding capacity and smaller pores which reduce soil aeration (Brandyk *et al.* 2002). A well aerated substrate is essential for fast growth of cloudberry rhizomes. Similar results have been obtained in Finland (G. Théroux Rancourt 2006, MTT Agrifood Research Finland, Sotkamo station, Finland, unpublished data). It has been observed that cloudberry plantations in soil with high bulk density were slower to colonize the site, with many plants only spreading out over a few centimetres in two years.

Therefore, it is important not to compact the site during its preparation or planting in order for it to keep adequate porous physical attributes for cloudberry. Use of machinery should be limited, and sites that did not sustain repeated machinery transit for many years should be favoured. Surface tillage (see section 1.3.2. Fertilization and cultivation methods), as recommended in Norway (Rapp 2004a), could be viable if there is little risk of the soil being compacted, among other things, when the machinery is allowed to move around freely (see Figure 1.10). Furthermore, this work should be done efficiently, by both using machinery on a limited surface area and by avoiding multiple passages.

Figure 1.10: Cloudberry planter developed by Norwegian company *Andøytorv*. Photo: Guillaume Théroux Rancourt.

Reclamation projects in cutover peatlands can occur where the peat has reached decomposition levels higher than those recommended (between H2 and H4), but growth rates are expected to be lower there (Rapp 2004a). We compared cloudberry growth in peats between H3 and H5 (Théroux Rancourt 2007). More new rhizomes were produced in H3 peat, and the total mass of rhizomes was marginally superior to that produced in H5 peat. This again ties in with the soil physical attributes, the H3 having a lower bulk density than the H5 peat. Planting in fibric peat is consequently recommended in order to enable the spread of cloudberry.

Thus, it is important to pay particular attention to the soil physical attributes. However, no standard is available to determine adequate range of values for cloudberry. Preliminary trials demonstrated that bulk density, total porosity and decomposition level are the factors which have most impact on cloudberry growth (G. Théroux Rancourt 2005, *Université Laval*, unpublished data).

1.4.2.2. Planting parameters

Planting can be done using either rhizome segments or ball plants such as the ones described in section 1.4.1.2. (Plant and rhizome production). Studies are being conducted in the Côte-Nord region in order to compare the survival rate of planted ball plants with those of rhizomes in the field.

The planting of rhizomes has been studied more closely than the planting of ball plants. We can harvest rhizomes which originate from natural clones in an area where they are plentiful, such as at the side of drainage ditches of exploited peatlands. Once harvested, the long rhizomes must be cut into small segments. The optimal length is at least 20 cm, as previously mentioned. These rhizomes must be planted at a depth of 5 cm instead of 10 cm (Bellemare 2007). The inability of deeply planted and greatly fragmented rhizomes to emerge can be explained by their lack of energy reserves. After cutting, the ramets are isolated and must survive adverse conditions, relying only on reserves stored in their perenial organs (Marshall 1990).

The moment at which planting occurs seems to be an important factor for success. According to results from a study conducted in the Côte-Nord region, the survival rate of rhizomes is higher when the planting takes place in the fall (Bellemare 2007). Therefore, rhizomes should be harvested in the fall and planted as soon as possible. The autumnal success can be explained either by a more active resumption of growth the following spring or by the fact that the spring harvest of rhizomes, when dormancy is over, induces more stress on the rhizome, reducing its chances of survival. However, a previous study did not report any differences between the spring and autumn harvests (Rapp *et al*. 2000).

During planting, rows of cloudberry rhizomes should be spaced between 25 and 33 cm from each other (Rapp 2004a). If the cost and quantity of the material to plant are not limiting factors, the planting density can be increased in order to reach high vegetation cover more rapidly and reduce the risk of weed infestations.

1.4.3. Soil moisture regime

1.4.3.1. Optimal level of the ground-water level

The recommended ground-water level in Norway is located between 30 and 50 cm below the surface (Rapp 2004a). This recommendation was tested in Quebec (Théroux Rancourt 2007). No differences were observed in terms of cloudberry growth between these water levels when compared either in greenhouses or on cutover peatlands (after peat extraction). However, there should be enough water to allow the plants to grow, and there should also be enough air to allow proper aeration of the substrate. It should also be noted that water levels below 30 cm in cutover peatlands is poor indicator of water availability at the surface (Price 1997). Therefore, we cannot strictly rely on the water level when choosing a site.

1.4.3.2. Water drainage

Fruit production is higher near drainage ditches (Østgård 1964). Trials were conducted in order to produce cloudberries on peat mounds where trenches were closer, but this experiment did not succeed because of the slow implantation of cloudberry plants. However, it was mentioned that the drainage of a peatland using trenches with a depth of 70 to 80 cm leads to a reduction in the productivity of cloudberries, even if there is a temporary increase in the yield following drainage (Kardell 1986).

Nonetheless, the importance of drainage resides in the fact that aeration needs to be improved without affecting the availability of water, which could not be achieved in the above-mentioned cases. In the Quebec trials, the water level was controlled using a dam located 25 or 50 cm from the surface (Théroux Rancourt 2007). This dam linked the blocked drainage ditches according to the recommendations for peatland restoration (Quinty and Rochefort 2003). This way, water was drained in the spring, which allowed for the increase of air thus helping the implantation process. A dam may not be necessary: the installation of an out-flowing water system which reduces the ground water level during the spring could be sufficient (Figure 1.11).

Figure 1.11: Dam used for trials on ground water levels at Pointe-Lebel (Quebec). Photo: Guillaume Théroux Rancourt.

1.4.3.3. Irrigation

The water required for cultivation comes from rainfall and ground water at the site of the plantation. No trial was conducted by adding water by way of irrigation. Because cloudberry grows in moist environments, this situation is not yet a concern. However, cloudberry needs an adequate amount of water for growth. A lack of water can decrease growth and can be fatal in case of drought, the plant being very sensitive to such conditions. After three years of growth, we observe that plants have a tendency to die on bare peat because the plants are subjected to more frequent unfavourable moisture conditions than under hay mulch (G. Théroux Rancourt, pers. obs.). Therefore, it is important to provide adequate moisture conditions where and when rhizomes are planted near the surface. This will be addressed in the section about the use of mulch.

1.4.4. Fertilization

Many cloudberry fertilization trials, in greenhouses, in natural environments and in cultures, have been conducted in both Fennoscandia and Canada (Table 1.3). Results are rather mixed and no absolute formulation or fertilization standards have been developed to this day. As for fertilization in natural environments, the Tromsø Agricultural Institute of Norway recommends applying 500 kg/ha of 14-14-19 fertilizer. This dose must be placed at a depth of 20 cm, and it is probably best to divide the dose by making several 20 cm deep holes per m^2. Depth fertilization reduces the amount of fertilizer available to weeds and optimizes the absorption of nutrients by cloudberry (Rapp and Steenberg 1977). Fertilization must be done within six months to a year after plantation, before the flowering period, when the ground has thawed, or after fruit harvest in August or September. According to the Norwegian cloudberry growers guide, this amount of fertilizer should be enough for ten years of cultivation (Rapp 2004a). However, other studies will have to be conducted on the subject.

1.4.5. Weed control

1.4.5.1. Competitive plants

In Europe, cloudberry's main competitive plants are *Empetrum hermaphroditum* and *Eriphorum* sp. Birch (*Betula* sp.) and Scots Pine (*Pinus sylvestris*) seedlings are also frequently observed in Finland (G. Théroux Rancourt, pers. obs.).

The use of mulch to eradicate competitive plants would be a more interesting approach than weeding (see section 1.4.5.2. Mulch). However, if mulching is not efficient, we can try other methods to control self-propagating plants. For example, vegetation can be mowed in the spring before cloudberry begins to grow (Mäkinen and Oikarinen 1974). This method is only effective over a short-term period, during which cloudberry produces its aerial roots, because vegetation will regrow vigorously during the summer. Ploughing could reduce the number of shrubs and give cloudberry more space. These methods mostly apply to natural peatlands. Manual weeding can also be done, such is the case for small birch seedlings on cutover peatlands (Rapp 2004a). If these attempts do not work, the use of herbicides could be an option. However, it is necessary to identify an active substance which is suitable for both peatland and cloudberry (Rapp 2004a).

European and Canadian plantations are still young and the magnitude of the competitive plant problem still needs to be evaluated.

1.4.5.2. Mulch

The use of mulch reduces weed infestation (Cushman *et al.* 2005). It is important to reduce the potential competition with these plants because cloudberry is not competitive in terms of the use of soil resources (Rapp and Steenberg 1977).

A few trials using mulch were conducted in cultivation of cloudberry (Figure 1.12). In Finland, an increase in the number of flowers was observed in sections of natural peatlands covered with hay mulch (Kortesharju 1986). Cloudberry yields under hay mulch was six times higher than on untreated plots on a drained forest peatland (Huikari 1972).

Figure 1.12: Pointe-Lebel experimental site (Quebec); presence of mulch and terraces. Photo: Mireille Bellemare.

The use of hay mulch could be advantageous for cloudberry. Temperatures and their variations are generally reduced when the plants are under mulch (Hicklenton *et al.* 2000, Ji and Unger 2001, Cushman *et al.* 2005). This could be profitable for cloudberry because during spring, its growth is reduced when temperatures are colder (Lohi 1974). Delaying flowering would be beneficial to avoid spring frosts, flowers being very sensitive to this stress (Kortesharju 1995).

However, hay mulch could have negative effects on the implantation of cloudberry rhizomes on cutover peatlands. In fact, the number of leaves produced during the two first years following implantation was lower under mulch than on bare peat (Théroux Rancourt 2007). This could have

Table 1.3: Cloudberry response (at the vegetative, floral, fruit or other state) to different types and dose of fertilizer applied in different habitats in Europe and Canada. (NS = non significant, (+) = positive response and (-) = negative response).

Fertilizer	Dose	Type of fertilizer	Application	Habitat	Vegetative response	Flower response	Fruit response	Other	Reference
Superphosphate Calcium	-	-	-	-	(+) (-)	-	-	-	Sandved (1959) in Mäkinen and Oikarinen (1974)
Phosphorus+Potassium Phosphorus+Potassium + Nitrogen	-	-	-	-	-	-	(+)	-	Lid *et al*. (1961) in Mäkinen and Oikarinen 1974
Calcium nitrate, Superphosphate and combination of both	15-30 $g/m^2/year$	Deliquescent salt	Aerial	Bog	(+)	-	(+)	-	Østgård (1964) (N.B. in 2 experiments out of 15 = significant increase of the yield)
Calcium nitrate + Superphosphate Complete fertilizer (11.5-12.5% N, 5.0-5.5% P and 14.5-15.0% K)	20-30 $g/m^2/year$	-	Aerial	Bog	-	-	(+)	-	Østgård (1964)
Potassium sulphate, Magnesium sulphate, Lime, B, Cu, Fe, Mn, Zn	-	Salt (soluble), salt (hydrated), powder	Aerial	Bog	-	-	Neutral or NS	-	Østgård (1964)
Organic fertilizer	-	Eagle feces	-	Mineral soil	(+)	(+)	-	-	Taylor (1971)
P^{32}-orthophosphate (+ $NaH_2PO_4 \cdot H_2O$)	10 mL/hole; 4 $holes/m^2$	Solution	In depth (10, 20, 40 and 60 cm)	Mire	-	-	-	Best assimilation of P: fertilization at 20-40 cm	Rapp and Steenberg (1977)
Phosphorus	-	-	In depth (10-20 cm)	Bog	Light	(+)	-	Duration of the effect: 3 years	Kortesharju and Rantala (1980)
Nitrogen	-	-	In depth (10-20 cm)	Bog	(+)	(+)	-	Duration of the effect: 3 years	Kortesharju and Rantala (1980)
Potassium	-	-	In depth (10-20 cm)	Bog	Light	-	-	Duration of the effect: 1 year	Kortesharju and Rantala (1980)

Table 1.3 (following)

Fertilizer	Dose	Type of fertilizer	Application	Habitat	Vegeta-tive response	Flower response	Fruit response	Other	Reference
Nitrogen, Phosphorous and Potassium alone and in combination	Depends on treatment	Depends on treatment	-	Field	-	-	-	Fruit maturation time: any or light effect	Kortesharju (1993)
Potassium phosphate	15 to 1000 ppm	Solution	Foliar	Greenhouse	NS	-	-	-	J. Zhou (in prep.)
Boronic acid	1.5 and 15 ppm (B)	Solution	Foliar	Cutover peatland	NS	-	(+) (1.5 ppm) (-) (15 ppm)	-	J. Zhou (in prep.)
Complete fertilizer	5 g/m^2	Powder	Aerial	Cutover peatland	NS	-	NS	-	J. Zhou (in prep.)
Agrophos	15-1000 and 2000 ppm	Solution	Foliar	Cutover peatland	NS	-	NS	-	J. Zhou (in prep.)
Complete fertilizer – N-P_2O_5-K_2O (15-15-18)	0-5-10-20-40-80 ppm (N)	Solution	Watering	Greenhouse	Neutral	-	-	High mortality	M. Bellemare, U.Laval, 2005 (unpubl. data)
Complete fertilizer – N-P_2O_5-K_2O (13-13-13) + Lime	0-2-4-6 and 8 g fertilizer/L of peat; lime: 1.3 kg/m³	Slow release fertilizer (pellets)	In depth (3 cm)	Greenhouse	(+) (for doses of 2 to 6 g/L)	-	-	-	Bellemare (2007)
Complete fertilizer (3-1-2 [NPK])	0 or 200 g/m^2 (+ 0.4 g/m^2 of 0-0-22 [NPK]), 5 times	Powder	Aerial	Nursery	(+) (higher root mass)	(+)	NS	(+) total number of bud produced	R. Gauci (in prep.)
NH_4NO_3	0.2 – 378 ppm N total	Solution	Hydroponics	Greenhouse	-	-	-	Better absorption of NH_4 than NO_3	J. Zhou (in prep.)

been caused by the slowing of rhizomes growth in moist peat, which was slower to warm up because of the mulch cover. The use of reserves could have been too great, and the rhizomes were considerably weakened once they reached the surface. It should be noted that in this experiment, the rhizomes may have been planted too deeply (see section 1.4.2.2. Planting parameters). However, after three years, we observed mortality in the plots which were not covered with mulch. In fact, hay mulch provides considerable improvement of moisture conditions easing, among others, the growth of reintroduced sphagnum fragments (Price 1997, Price *et al.* 1998). The improvement of moisture conditions could be favourable for cloudberry, which may not withstand the drier conditions of bare peat. Additional studies on the subject will have to be conducted.

It would be preferable to plant cloudberry in a peatland which has been restored two or three years earlier in order to benefit from the improvement of moisture conditions due to mulch and the recently formed moss cover, and to avoid the initial negative effect of under-decomposed mulch.

1.4.6. Protection against the cold

Cloudberry is very sensitive to cold and frost, so many methods of protection have been proposed. These methods are used to delay flowering in the spring. Two types of method will be described here: physical protection and windbreakers. The use of mulch has been discussed previously.

1.4.6.1. Physical protection

Physical protection methods consist of protecting cloudberry at ground level. The first method is the spring flooding, which was proposed in Finland in order to prevent the deleterious effects of frost and to slow down the growth of plants (Mäkinen and Oikarinen 1974). We have to be careful not to prolong flooding, which could cause growth problems. It is also important to avoid planting when there is excess water in the ground.

The use of plastic mulches was also studied. They could increase soil temperatures by 1.5 to 5 ºC, thus reducing damage caused by frost (Kortesharju 1988).

Other protection methods were proposed, for example, placing the cultivation site near an open water source, which would stabilize temperatures (Mäkinen and Oikarinen 1974). Organic mulches have also been tried (peat, wood bark or chip, seaweed), as well as mineral mulches (sand, gravel). The results obtained with the organic mulches were similar to those obtained with the hay mulch. The mineral mulches, according to their colours, increased the soil minimal temperature, therefore reducing the risk of frost. However, the weight of these covers results in pressure on the ground, which in turn increased the ground water level and can affect growth of cloudberry (Mäkinen and Oikarinen 1974).

1.4.6.2. Windbreakers

Windbreakers sometimes have a beneficial effect on the production of cloudberry by increasing its vegetative growth, its flowering and its fruit yield, and this, two years after the implantation (Østgård 1964, Mäkinen and Oikarinen 1974). This is probably caused by the increase of temperature and improvement of pollination conditions. Windbreakers, in the form of a vegetation hedge or a snow fence, are beneficial in large open peatlands (Rapp 2004a). It could be advantageous to create semi-open forests since yields in these habitats are usually more stable from year to year than in open peatlands (Yudina 1993). However, there should be good air circulation to avoid that cold air stagnates over the plants and causes frost. The recommended porosity for windbreakers is between 40 and 50% (Perreault 2005).

Trials for the implementation of windbreakers were conducted in both Norway and Canada (Figure 1.13). In Canada, the windbreaker effect on cloudberry plantations in cutover peatlands was tested using snow fences that were installed perpendicularly to the dominant winds (South-West). Rows of 10 cloudberry rhizomes were planted on both sides of the fences. The snow fence was 0.45 m in height per 5 m in length with porosity of approximately 37%. The windbreaker did not have any impact on cloudberry survival and growth rates. However, the expected effect the windbreaker should have is more on fruiting than on survival. Since no fruit was produced during the study, this parameter could not be studied. We observed no difference in terms of microclimate conditions between the protected plots and those exposed to the wind in the spring. However, in the summer, plots that were protected by the snow fence were those where the variation in temperature was higher (Bellemare 2007). Snow fences certainly reduced the speed of the wind, which could favour pollination. A long-term follow-up should allow us to better measure the impact that this type of protection provides for cloudberry.

1.4.7. Pollination

Pollination of cloudberry is entomophilous, meaning that fertilization is provided by insects (Figure 1.14). Sampling and controlled introduction experiments indicated that four insect families (Apidae, Halictidae, Muscidae, and Syrphidae) are the most frequent visitors and the most efficient pollinators of cloudberry (Brown 2005). Cloudberry seems to be the ideal plant to satisfy the requirements of small flies with its simple open flowers and ideal amounts of pollen and nectar. The pollinators seems to prefer male flowers over the female's (Ågren *et al.* 1986). Female flowers could attract insects by what we call pollination by deception, which means that they fool the insects by trying to appear as male flowers (Ågren 1987b). However, in the Côte-Nord region, female flowers produce significantly more nectar than their male counterparts (Brown 2005).

A

B

Figure 1.13: Trials on the use of windbreakers in Norway (A) and at Pointe-Lebel, in Quebec (B). Photo: A) Guillaume Théroux Rancourt, B) Mireille Bellemare.

Figure 1.14: Pollination by an insect. Photo: Mireille Bellemare.

1.4.8. Diseases and pests

Cloudberry attracts a few pests, although they don't seem to affect fruit yield in natural habitats (Kortesharju 1988). Larva from two species of moths (*Capua vulgana* and *Olethreutes (Agyroploce) schulziana*) are regularly observed eating cloudberry flowers in Great Britain (Taylor 1971). Moreover, the *Galerucella nymphaeae* beetle is a defoliator of cloudberry that was inventoried in Finland. There was a yield reduction linked to this insect in certain locations and most important damages occurred during the fruit maturation period (Mäkinen and Oikarinen 1974).

As for pathogens, a few fungi were observed on cloudberry, such as *Mycospaerella joaerstadii,* which should not be of great importance (Mäkinen and Oikarinen 1974). At the beginning of the summer in Norway, certain stromatic fungi (*Cibora latioes*, *Rutstroernia chamaemori* and *Sclerotina tetraspora*) are sometimes observed on cloudberry (Thiem 2003). Moreover, *Botrytis cinerea*, the grey mould, can attack fruits that are decomposing.

Frequent fungal diseases, such as *Peronospora sparsa*, or downy mildew are observed. However, we do not know if this fungus affects the yield. Another fungal disease which appears in the form of black stains on the fruits has also been reported. When analyzed, a ribosomal genetic sequence similar to *Sclerotinia* sp. was identified (S. Kärenlampi, 2003, University of Kuopio, Finland, pers. comm.).

No solution has been found to solve these pest and pathogen problems. However, these problems are not very serious; the increase in yield is a more important issue to this date.

1.4.9. Field maintenance and rejuvenation

Currently, there is no recommendation that addresses the rejuvenation of fields other than applying fertilizer every ten years.

1.4.10. Cultivation monitoring

On cutover peatlands, it's important to monitor the <u>survival rate</u> during the first year by counting the number of shoots. Afterwards, a monitoring of the increase in plant cover is needed in order to insure that growth is going on efficiently. This is based on the <u>number of plants per m^2</u> and should be estimated during the first years while cloudberry takes hold of its environment. Growth can be slow, as observed in many cultivation sites in Quebec and Finland.

It is also important to estimate the <u>number of female flowers and fruits per m^2</u>, in natural peatlands as well as in plantations. This gives an indication of the fruit abortion rate and <u>yield.</u> Rapp (2004a) reports expected yields of 50 to 200 kg/ha for cultivation sites. However, we must not forget that cloudberry yield can vary from one year to another (see Table 1.2 for other examples of yield in natural habitats).

1.5. Fruits

1.5.1. Harvest

The fruit is ripe and ready to be harvested when it is a yellowish-orange colour, and easily detached from the receptacle. To insure proper quality, berries (with less than five drupelets) and fruits with black stains should not be picked (Røthe *et al.* 2000). The maturation is spread out over time because flowering and pollination are processes that take place over several days (Rapp 2004a). Therefore, it is preferable to pick fruits at least three times in order to harvest most of the fruits.

For now, harvest is done by hand (Figure 1.15) by fruit pickers whose numbers are decreasing, and who are getting older (Saastamoinen 1998). In Finland, foreigners are sometimes brought in to compensate for the lack of pickers (Granqvist 2006).

Figure 1.15: A good fruit harvest. Photo: Guillaume Théroux Rancourt.

The best container for picking fruits is a hard receptacle, between 3 to 5 L, to avoid having fruits which were picked first to be crushed by those on top (Rapp 2004a). The fruits have to be carried with precaution. Transport by tractor, with its vibrations, can diminish berry quality by compacting the fruits, giving them a jam-like consistency (Røthe *et al.* 2000).

In Norway, most of the fruits sold are not washed nor classified (Røthe *et al.* 2000). Consequently, an attempt has been made to define four quality grades in order to develop new products:

- Grade 1: Individually frozen fruits. Top quality.
- Grade 2: "For jam", for jams and jellies.
- Grade 3: "For juice", for the concentrated juices production.
- Grade 4: "Garbage", fruits with black stains, leaves, etc.

After harvest, once classification is completed, roughly 9% of the fruit in a 10 kg container is grade 1 and most of the rest is grade 2. When sorting is done in the field during harvest, the percentage of fruits of grade 1 averages between 32 to 44%. Grade 1 fruits should have a diameter of at least 15 mm.

1.5.2. Preservation

Over the short-term, fruits should be kept in a refrigerator or in a cold storage unit. Thanks to the high benzoic acid content in the fruit (Rapp 2004a), many weeks can go by before fruits sustain damage caused by mildew during storage. The freezing process does not affect taste and the vitamin C content remains stable for at least six months at a temperature of -20 °C. Sugar can be added at a ratio of 250 g of sugar for 750 g of fruit during fruit preservation process.

1.5.3. Potential uses

In Finland, a small portion of harvested fruits is sold to the industry (Saastamoinen *et al*. 2000). Besides the traditional uses by the pickers, the industry is developing many products. Here is a brief overview of the possibilities for the fruits, as well as for other parts of the plant.

1.5.3.1. Food products

The cloudberry fruit is delicious when consumed fresh. Like other berries, it can also be cooked in pies, cakes, jams and other household products. Besides, in the Côte-Nord region, some handcrafted cloudberry-based products are sold to the public. Many craft or industrial companies (located in Fennoscandia), prepare and commercialize cloudberry-based food products, mainly jams and jellies. One can also come across frozen fruit packages. In Fennoscandia, cloudberry is available in supermarkets in different forms, which are sometimes incorporated in yogurts, muffins and ice cream. Furthermore cloudberry can be consumed in the form of alcohol: many companies in Finland, Quebec and Newfoundland offer such liquors.

Cloudberry leaves, combined with other plants, are used to make teas and herbal teas.

The following is a list of products made with cloudberries. It is a non-exhaustive list and many other companies make commercial use of cloudberry.

- Teas and herbal teas:

  Northern Delight Teas (Avataq Cultural Institute, Inukjuak, QC, Canada)
  http://www.avataq.qc.ca/tea_files/tea_en.cfm

- Alcohols :

  Liqueur Chicoutai (La Maison des futailles, Anjou, QC, Canada)
  http://www.futailles.com/fran/3_0/chicoutai.html (English site under construction)

  Exotic Wild cloudberry (Bakeapple) Wine (Rodrigues Winery, Whitbourn, NL, Canada)
  http://www.rodrigueswinery.com/cloudberry.asp

  Lapponia Lakka, Cloudberry liquor (V&S Finland Oy, Finland)

- Jams, fruit compotes, chocolates, etc.:

  Les délices de la Basse-Côte-Nord (Blanc-Sablon, QC, Canada)

  La Maison de la Chicoutai (Rivière-au-Tonnerre, QC, Canada)
  Owner: Bruno Duguay; Tel: 418-465-2140 ;
  email: lamaisondelachicoutai@globetrotter.net

  Confiserie la Mère Michèle (Baie-Comeau QC, Canada)
  http://www.tourismemanicouagan.com/en/fiche.asp?id=1495

  Darktickle company (Griquet, NL, Canada)
  http://www.darktickle.com/default.aspx

1.5.3.2. Non-dietary uses

Cloudberry is sometimes introduced as an ornemental plant in landscapes (Small and Catling 2000). In Finland, it is possible to purchase sets of ten cloudberry plants from nuserymen (Peuraniemen Taimitarha, Kajaani, Finland): 8 females and 2 males, the two originating from Norwegian cultivars.

Other than their dietary and ornemental uses, cloudberry fruits can also be used in the making of cosmetics. The seeds are crushed, and the oil obtained is incorporated to creams and cleansers. This oil is interesting for the cosmetology field because it is rich in essential fatty acids (omega-3 and 6), in antioxidants and in carotenoids.

Cloudberry's unique aroma is also commercialized. Cloudberry can be found as an essential oil, which is used to sent soaps and candles among other products. We could also find it in certain perfumes.

Here is a non-exhaustive list of companies using cloudberry.

- Cosmetics:

  Cloudberry and honey soap (Mellis, Finland)
  http://www.mellis.fi/index.jsp?pid=679

  Cream and skin care (Lumene, Finland)
  http://www.lumene.com/default.asp?docId=14207

  Oil from cloudberry seeds for skin care (Aromtech, Finland)
  http://www.aromtech.com/

  Skin care (skyn ICELAND, New York, NY, United States)
  http://www.skyniceland.com/

  Fragrance, essential oils (From Nature With Love, United States)
  http://www.fromnaturewithlove.com/soap/FO-S.asp

1.6. Conclusion

Cloudberry cultivation seems to offer promising avenues to give added commercial value to cutover peatland restoration. Moreover, resorting to more performant cultivars would improve fruit yield and could help to revive northern regions where the socio-economical context is precarious. It is a very interesting fruit because of its medicinal proprieties and its unique aroma. However, many factors still need to be studied in order to improve the yield of this new crop, thus making it profitable. Among other things, we should better understand the biology of this plant, notably its physiology, in order to improve its cultural practices.

Despite being documented for almost fifty years, cloudberry cultivation is still in its infancy. In Fennoscandia, its total production surface is only 15 ha. Generally, the fields are less than five years old and few of them have produced fruit to this day. Thus, it is too soon to know if the actual techniques are efficient or not. Research must continue in order to better cultivate this fruit which is still wild on both sides of the Atlantic.

Currently, results from researches conducted in Quebec allow us to make a few recommendations. On exploited peatlands, we recommend planting rhizomes of more than 20 cm in length, at a depth of 5 cm, in the fall. It is also recommended to plant in peat that is less decomposed (H4 and less) and to limit the use of machinery during soil preparation. When combined with a peatland restoration project, it would be better to plant cloudberry two or three years after restoration in order to take advantage of the newly formed moss cover (better moisture conditions) and to avoid or limit the negative effects of hay mulch. If necessary, the use of hay as winter protection could be conceivable, but we must be mindful of mulch density, mostly for young plantations. While waiting for the marketing of cultivars selected from local clones, the Norwegian cultivar Fjordgull is, for the time being, recommended because of its good survival and growth results.

On natural peatlands, the application of fertilizer at depths of 10 to 20 cm combined with the severing of rhizomes increase the density of roots, flowers, and, in later seasons, the yield of fruits.

1.7. References

1.7.1. Useful resources

1.7.1.1. Where to obtain cloudberry rhizomes

Peuraniemen Taimitarha
Owner: M. Kari Komulainen
Peuraniementie 65
87250 Kajaani, **Finland**
Telephone: +358-40-7415457
Email: info@peuraniementaimitarha.fi
Web site: http://www.peuraniementaimitarha.fi/
(in Finnish)

Eggen Gartneri
Owner: M. Dagfinn Eggen
Klungset
8200 Fauske, **Norway**
Telephone: +47-75644954
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Photo: Julie Bussières

Chapter 2:

The black chokeberry

by

Julie Bussières, Stéphanie Boudreau and Line Rochefort

Photo: GRET

Photo: Julie Bussières

2.1. Introduction

The black chokeberry is native to North America, but its production was first popularized in Eastern Europe and in the former Soviet Union for its nutraceutical proprieties (Kask 1987, Finn 1999).

This plant is found naturally in peatlands, and its cultivation in cutover peatlands (after peat extraction) has been studied since 2000 at the Saint-Bonaventure site (Fafard & Frères ltée), in Quebec. These trials have shown that the species has both good growth capacity and fruit yields on cutover peatlands, and can be used for different types of restoration or reclamation projects (Clément-Mathieu 2004, Bussières 2005, Bussières *et al.* 2008).

2.2. Species biology

2.2.1. Names

- *Aronia melanocarpa* (Michx.) Ell.

  Synonyms: *Photinia melanocarpa* (Michx.) K.R. Robertson & Phipp (new accepted name), *Aronia arbutifolia* (L.) Pers. var. *nigra* (Willd.) Seymour , *Aronia nigra* (Willd.) Koehne, *Pyrus arbutifolia* (L.) L. f. var. *nigra* Willd, *Pyrus melanocarpa* (Michx.) Willd., *Sorbus melanocarpa* (Michx.) Heynh.

  Vernacular names:

  English: black chokeberry
  French: *aronia noir, gueules noires*

  Family: Rosaceae

2.2.2. Distribution and habitat

Black chokeberry distribution area stretches from Newfoundland to Minnesota and from Iowa toward the South West (Gleason and Cronquist 1991, Croisetière 2006, Natural Resources Canada 2007). Figure 2.1 is a map showing the species distribution in Quebec and Newfoundland based on *A. melanocarpa* specimens preserved at the Louis-Marie Herbarium of *Université Laval* in Quebec.

Black chokeberry grows in wetlands and particularly acidic environments (Marie-Victorin 1995). In Quebec, chokeberry cultivation is not very popular. There are roughly fifteen producers in Charlevoix, Lac-Saint-Jean and Quebec regions (Croisetière 2006).

2.2.3. Plant characteristics

2.2.3.1. Vegetative parts

Black chokeberry is a 1 to 2 m high and 1.5 m wide shrub, and has a globular carriage (Figure 2.2A), that gets denser by producing new stems at its base by suckering. Its foliage is dark green and shinny during the summer (Figure 2.2B) and becomes red and falls in autumn (Richer *et al*. 1997, Pellerin 2006).

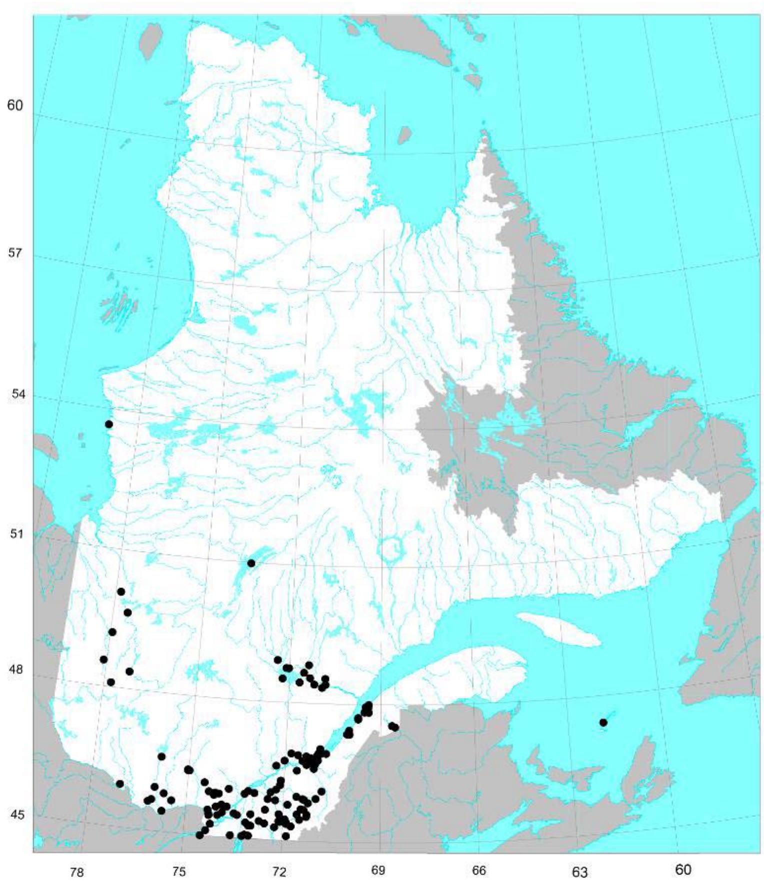

Figure 2.1: A map showing the species distribution in Quebec and Newfoundland based on *Aronia melanocarpa* specimens preserved at the Louis-Marie Herbarium of *Université Laval* in Quebec (prepared by Kim Damboise, Louis-Marie Herbarium).

A

B

Figure 2.2: A) Black chokeberry shrub planted in Saint-Bonaventure (Quebec) and B) black chokeberry leaves. Photos: (A) PERG and (B) Gilles Ayotte.

2.2.3.2. Flowers

In May, black chokeberry shrubs are especially interesting from an aesthetic point of view when they produce a multitude of small white flowers (1.5 cm in diameter) in corymbs (Figure 2.3).

2.2.3.3. Fruits

Fruits can reach 1 cm in diameter, they are red at the beginning in summer and turn dark purple to black when reaching maturity in August and September (Figure 2.4).

Because of their high anthocyanin content (Appendix 1; Oszmianski and Sapis 1988, Wu *et al.* 2004), black chokeberry fruits are among those with the highest antioxidant level (Kähkönen *et al.* 1999), and possess recognized antimutagenic properties (Gasiorowski *et al.* 1997). Despite being very astringent and sour-tasting, they can be consumed fresh. They can also be incorporated to different products such as juice, alcoholic or energetic beverages, pharmaceutical products and food colouring.

The fruits are also consumed by birds, which makes the species particularly interesting for restoration and reclamation plans.

Figure 2.3: Black chokeberry flowers. Photos: Gilles Ayotte.

A

B

Figure 2.4: Black chokeberry fruits in the middle of summer (A) and at the end of summer (B) in Saint-Bonaventure (Quebec). Photos: Julie Bussières.

2.2.4. Factors affecting yield

Black chokeberry is relatively easy to cultivate because it is known for its tolerance to frost, to different types of soil and to moisture regimes, as well as for its low susceptibility to diseases and pests (Richer *et al*. 1997, King 2002, Pellerin 2006).

Experiments in cutover peatlands have shown that adding fertilizer is necessary for the establishement of black chokeberry plantations and to obtain large yields (see section 2.3.4. Fertilization).

2.3. Cultural practices

2.3.1. Plants

Despite being an easily transplanted species (Rousseau 2002), it's recommended to use seedlings in containers rather than bare-rooted plants in order to reduce the stress caused by planting (Richer *et al.* 1997). For now, only indigenous cultivars have been tested in cutover peatlands (Bussières *et al.* 2008), but nurseries also offer different decorative cultivars or plants with improved fruit yield. It's also possible to produce your own seedlings using seeds, propagation by softwood cuttings (taken at the end of May or the beginning of June; Rousseau 2002) or by dividing established plants (the black chokeberry produces new stem suckers at its base).

2.3.2. Planting

2.3.2.1. Soil

Black chokeberry can be planted in practically any type of soil (Richer *et al.* 1997, Pellerin 2006) and abandoned fields after peat extraction are suitable for this species, even those with a thick residual peat layer (Bussières *et al.* 2008). Within a peatland management plan, black chokeberry has not yet been tested in combination with restoration techniques, but when tested, it would be better to select relatively dry areas because the plants may not survive an extended flood.

2.3.2.2. Period

Even if no planting period was tested in cutover peatlands, it is recommended to plant black chokeberry seedlings early summer, after the site is drained of water from the snow melt and before the heat and droughts of summer.

2.3.2.3. Spacing

For fruit production, it is recommended to space plants 1.5 m apart and keep rows 3 m apart (Figure 2.5). This distance is generally sufficient for mechanized operations, notably for weeding using a lawn tractor. Note that weeding is not essential for black chokeberry cultivation (see section 2.3.5. Weed control). For naturalization purpose, seedlings can be planted in groves while accounting for the plants final width of approximately 1.5 m (Richer *et al.* 1997).


A


B

Figure 2.5: Spacing between rows (A) and black chokeberry seedlings (B) in Saint-Bonaventure (Quebec). Photos: PERG.

2.3.3. Soil moisture regime

The black chokeberry is found in natural peatlands and in a variety of habitats with moisture regime varying from dry to moist (Richer *et al*. 1997, Rousseau 2002). Optimal drainage on cutover peatlands has not been tested, but previous experiments suggest that black chokeberry can resist to relatively low water levels (as low as 50 cm deep for a considerable part of the growing season). Moreover, this species also seems resistant to temporary spring floods. Usual spacing between drainage ditches during peat harvest, about 30 m, is suitable for the cultivation of black chokeberries, without additional drainage or irrigation. However, it is convenient to flatten the peat field surface before planting in order to aid the retention of rain water.

2.3.4. Fertilization

Experiments conducted on cultivation of black chokeberries in cutover peatlands have proven that fertilization is necessary. The recommended dose for planting is 130 g/seedling of 1.7-9.4-14.4[4]. This dose is enought to insure the establishment as well as strong growth of seedlings for many years. However, application every year or every two years is recommended in order to optimize growth and favor fruit production. European experiments aiming to develop black chokeberry fertilization management confirm the importance of annual fertilization at different phenologic stages to optimize fruit yield (Jeppsson 2000).

In light of different trials conducted on chokeberries in cutover peatlands, we recommend the use of a fertilizer composed of urea, rock phosphate and potassium muriate.

The fertilizer can be applied on the surface immediately after planting, in a radius of 10 cm around seedlings. Different trials tested whether applying fertilizer in the ground could be

[4] $N-P_2O_5-K_2O$

advantageous. Application of fertilizer by injecting it into holes around seedlings reduced weed infestation, but didn't have any positive effect on black chokeberry growth because it is resistant to competition. However, a trial where fertilizer was incorporated into the ground using a rotovator, before plantation, allowed a better seedling establishment..

Finally, black chokeberry is adapted to acidic habitats. Addition of lime was tested in cutover peatlands, but has no positive effect.

2.3.5. Weed control

Experiments conducted by the Peatland Ecology Research Group (PERG) and Fafard & Frères ltée have shown that black chockeberry is resistant to agricultural weed competition and competition from species typically found in acidic habitats. Therefore, it's not necessary to take into account methods of weed control.

However, a few methods can be considered if the presence of weed becomes a problem, for example, due to a nearby peat harvesting area. Experiments have shown that using plastic mulch efficiently control weed while helping black chokeberry growth in cutover peatlands. Whereas, it's important to note that application of plastic mulch requires specialized equipment (anticipate costs) and that fertilization must be done before planting begins. Nevertheless, applying fertilizer by injection in the ground (dividing the application amount in two or three holes of 5 cm in depth, about 10 cm from seedlings) can be a cost efficient and effective way to avoid weed infestations.

If necessary, a lawn tractor can be used to help weeding a plantation spread out in rows.

2.3.6. Protection against the cold

This species is rarely affected by frost (Canadian hardiness zone 3a to 4a; Rousseau 2002, Pellerin 2006), does not require winter protection and can even be used as a windbreaker for other cultivated species or to increase accumulation of snow in specific areas.

2.3.7. Diseases and pests

Documentation on black chokeberry indicates that this species has very few diseases or pests (McKay 2001, King 2002, Rousseau 2002, Strik and Finn 2003, Pellerin 2006). Observations of damages being caused by diseases or pests on plantations or natural populations of black chokeberries are strictly anecdotal. If these shrubs are cultivated for their fruits, it is important to watch out for birds, who quite like the fruits during autumn, and eventually develop preventive measures against birds (auditory, visual methods or nets; Carrier 2000).

2.3.8. Field maintenance and rejuvenation

Black chokeberry requires little trimming (Richer *et al.* 1997). It is recommended to trim damaged parts when necessary and to practice selective trimming of older branches every five to seven years in order to enable light to penetrate and reach the interior of the plants (McKay 2001). Excessive suckering of plants has not been observed yet in cutover peatlands, but in conventional plantations, it is recommended to thin out rows when suckers take too much space. This facilitates maintenance and cultivation activities and keeps light penetrating the inside of the plants, preventing negative effects on fruit yeild.

2.3.9. Cultivation monitoring

Survival is a key benchmark for any plantation. The survival rate of black chokeberry is generally very good (Richer *et al.* 1997), even in cutover peatlands (Bussières *et al.* 2008g). The plant's width and height are also interesting variables to measure if you want to evaluate the status of your plantation. It would then be possible to compare your results with those presented by the *Réseau d'essais de plantes ligneuses ornementales du Québec* [Quebec ornamental wood plant testing network] (REPLOQ; Richer *et al.* 1997) for black chokeberry plants measured from years one to five after plantation in different regions of Quebec (l'Assomption, Sainte-Clotilde, Sainte-Foy, La Pocatière, Normandin and Kapuskasing). It's important to know that when comparing results to those mentioned above, plants tested in cutover peatlands by the PERG and Fafard & Frères ltée have shown similar development but were delayed by approximately one growing season (Table 2.1; Bussières *et al*. 2008).

Table 2.1: Height and width of black chokeberry plants studied from years 1 to 6 after plantation in cutover peatlands (Saint-Bonaventure, Quebec). Excerpted from Bussières (2005) and Bussières *et al.* (2008).

Age (years)	Height (cm)	Width (cm)
1	30-55	—
2	60-80	45-75
3	70-80	70-80
5	105-115	—
6	130-150	140-165

Fruit yield is of course an important variable to measure in the context of fruit production. Commercial plantations on mineral soil reach their full fruit production capacity after an average of five years (McKay 2001). In Quebec, yields of 1.9 kg/plant have been recorded in cutover peatlands after six years (Bussières *et al.* 2008), in mineral soil, researchers from the *Institut de recherche et de développement en agroenvironnement* [Institute of Research and Development in Agroecology] (IRDA) noted yields of 2.4 kg/plant (Rousseau and Bergeron 2003). Yields of 1.9 kg/plant were also recorded in Sweden for plants ranging three to six years old (Jeppsson 2000) while Kask (1987) mentioned yields reaching 6 kg/plant in the best orchards of former Soviet Union.

2.4. Fruits

2.4.1. Harvest

Black chokeberry fruits can be harvested manually or mechanically using a black currant or blueberry harvester (Jeppsson 1999, King 2002). They are subjected to little mechanical breach during handling and transportation.

2.4.2. Potential uses

2.4.2.1. In restoration

Integrated to restoration plans (in groves or in windbreaker hedges), black chokeberry will notably aid in the return of birds typically found in peatlands, by giving them shelter and food (fruits and insects), in addition of providing landscape aesthetic.

2.4.2.2. Windbreaker hedges

Black chokeberry is a species of choice for windbreaking hedges of average height (one to two meters in height) in all restoration or reclamation projects in cutover peatlands. Windbreaker can be implemented in order to protect other cultivated plants, protect harvested, abandoned or restored sites from wind erosion or increase snow accumulation in specific areas.

2.4.2.3. For fruit production

Black chokeberry fruits are among those with the highest level of antioxidants and vitamin C. They are not very pleasant to taste when consumed fresh because they are very astringent and sour, but they are incorporated in different products such as juices, alcoholic or energetic beverages, teas, syrups, jellies, pharmaceutical products and food colourings (Oszmianski and Sapis 1988, McKay 2001, King 2002). This fruit is commercially produced in United States and in Europe since the 1930's (Kask 1987).

2.5. Conclusion

Black chokeberry is easily cultivated in cutover peatlands; it needs little maintenance and constitutes an excellent asset for many types of restoration or reclamation projects in abandoned peatlands after peat extraction.

Even if the market for its fruits is not well-developed in Eastern Canada, odds are that demand will increase once the black chokeberry's nutraceutical properties are known better.

2.6. References

2.6.1. Useful resources

2.6.1.1. Key informants

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Quebec (Quebec) G1P 3W8
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Email: carl.boivin@irda.qc.ca

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Photo taken from: http://www.parairiesberries.com/

Service-berry, Shad-bush - Amelanchier alnifolia

Taken from: http://www.swsbm.com/Images/Walcott.html

Chapter 3:

The serviceberry

by

Julie Bussières, Stéphanie Boudreau and Line Rochefort

3.1. Introduction

Serviceberries (*Amelanchier* sp.), including many species called “small pears”, are not well-known but produce fruits that are enjoyed by many.

For the time being, the only planting trials conducted in cutover peatlands have been done with the Saskatoon Berry (*Amelanchier alnifolia*). It’s an indigenous species in Western Canada where commercial cultivation is growing (Mazza and Davidson 1993, St-Pierre 1997, Manitoba Agriculture, Food and Rural Initiatives 2006, Ozga *et al.* 2006). Our trials in peatlands at Saint-Bonaventure (Fafard & Frères ltée) have demonstrated that this species is poorly adapted to conditions found in cutover peatlands. In fact, we observed good survival rates, but very low growth rates as well as symptoms of important deficiencies (Clément-Mathieu 2004a).

However, other similar species could show interesting potential in cutover peatlands, notably the Bartram serviceberry (*Amelanchier bartramiana* (Tausch) Roemer.) which is found in natural peatlands. No trials have been conducted on peat to this day; therefore, no recommendations have been made, but certain leads for research are proposed here.

3.2. Species biology

3.2.1. Names

Serviceberry's taxonomy is confusing. According to sources, some taxa are considered as species, subspecies, varieties or even synonyms. All serviceberry species are grouped under the *Amelanchier* genus, and different common names, particularly in English, are used to designate its genus: Saskatoon (Indian name that was given to a prairie town), juneberry, serviceberry, shadbush, etc. (Marie-Victorin 1995). The serviceberry taxonomical family is Rosaceae.

Here is the taxonomical description for the two species discussed in this chapter:

- *Amelanchier alnifolia* (Nutt.) Nutt. ex M. Roemer (Figure 3.1A)

  Synonyms: *Amelanchier alnifolia* Nutt., *Aronia alnifolia* Nutt., *Amelanchier humilis* Wiegand (Claude Roy, Louis-Marie Herbarium, pers. comm.)

  Vernacular names:

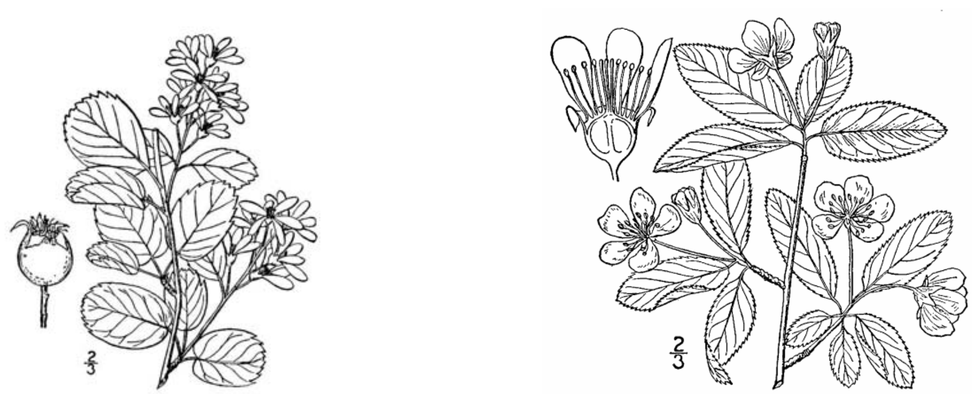
  English: Saskatoon berry, low shadbush, saskatoon, juneberry, serviceberry
  French: *amélanchier à feuilles d'aulne, amélanchier alnifolié, amélanchier bas, petites poires, amélanchier de Saskatoon*

- *Amelanchier bartramiana* (Tausch) M. Roemer (Figure 3.1B)

  Synonyms: *Pyrus bartramiana* Tausch, *Amelanchier oligocarpa* (Michx.) M. Roem.

  Vernacular names:

  English: mountain juneberry, mountain serviceberry, Bartram's shadbush, small pears, Bartram's chuckleypear, oblongfruit serviceberry
  French: *amélanchier de Bartram, amélanchier boréal, petites poires*



A B

Figure 3.1: A) *Amelanchier alnifolia* and B) *Amelanchier bartramiana.* Images taken from: Britton and Brown (1913) in the USDA-NRCS PLANTS Database (2007).

3.2.2. Distribution and habitat

Amelanchier alnifolia is a species indigenous to Canadian prairies, Northwest Territories, Nunavut, Yukon, Alaska and British Columbia, as well as in Northwest and North Central United States (Marie-Victorin 1995). Figure 3.2 is a distribution map of the species in Quebec and Labrador based on specimens preserved at Louis-Marie Herbarium of *Université Laval* in Quebec.

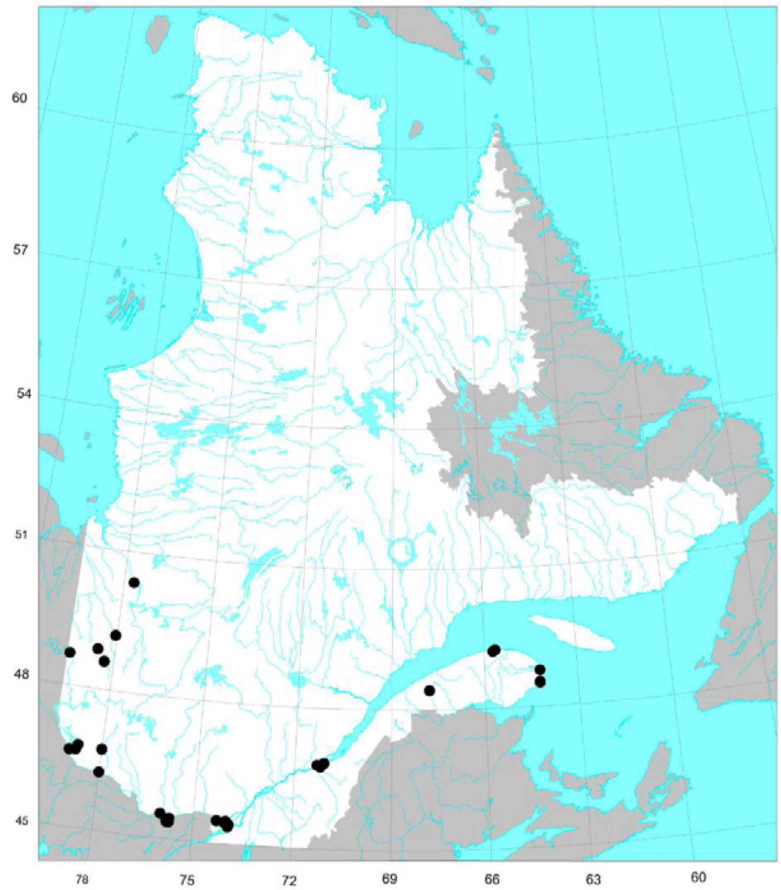


Figure 3.2: Distribution map of *Amelanchier alnifolia* in Quebec and Labrador based on harvest coordinates of specimens preserved at Louis-Marie Herbarium of *Université Laval* in Quebec (prepared by Kim Damboise, Louis-Marie Herbarium).

Amelanchier bartramiana (Tausch) Roemer is the most boreal serviceberry species in Quebec; it grows as far as the center of Ungava (Figure 3.3; Marie-Victorin 1995). It also grows in Labrador, in Maritime Provinces, in Ontario and in North Eastern United States (Gleason and Cronquist 1991, Natural Resources Canada 2007). This species grows in acidic soils of eastern and northern Quebec (Marie-Victorin 1995).

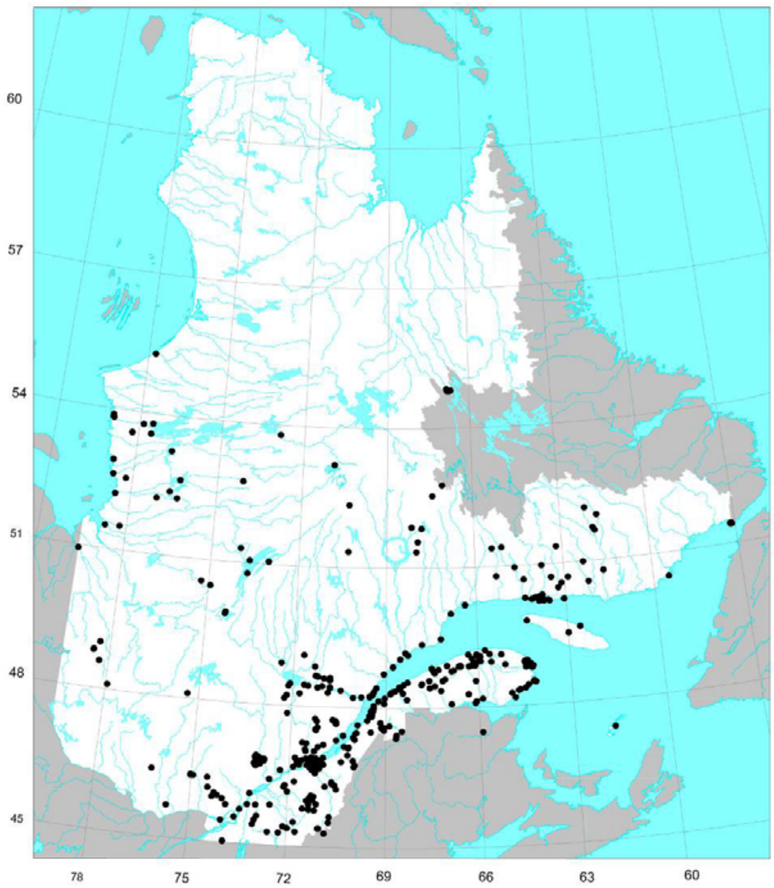


Figure 3.3: Distribution map of the *Amelanchier bartramiana* in Quebec and Labrador based of harvest coordinates of specimens preserved at Louis-Marie Herbarium of *Université Laval* in Quebec (prepared by Kim Damboise, Louis-Marie Herbarium).

3.2.3. Plant characteristics

3.2.3.1. Vegetative parts

Serviceberries (*Amelanchier* spp.) are shrubs of various heights which are even considered small trees. They are closely related to the apple tree, the hawthorn and the American Mountain Ash. They are perennial and ligneous fruit shrubs able to adapt to a wide range of soil and weather conditions. In addition to a root system combining a vertical central root and lateral roots, serviceberries produce rhizomes (underground roots) which allow vegetative propagation (Marie-Victorin 1995).

Amelanchier alnifolia is a shrubby species that can reach heights of 6 m, whereas the *A. bartramiana* measures 50 cm to 2.5 m high.

3.2.3.2. Flowers

Flowers appear in spring, simultaniously leaves are produced. Flowers of *Amelanchier alnifolia* are grouped in terminal racemes (1 to 20 flowers; Figure 3.4), whereas the ones of *A. bartramiana* generally stand alone or in pair in leaf axils (Figure 3.1).

Flowers, usually white, are hermaphrodite and pollinated by bees.


A


B

Figure 3.4: *Amelanchier alnifolia* in bloom.
Photos: A) Andy Huber, http://www.mnh.si.edu/lewisandclark/popup.cfm?type=species&id=1259; B) http://www.mt.nrcs.usda.gov/technical/ecs/forestry/serviceberry.html.

3.2.3.3. Fruits

Fruits, called "small pears" or "Saskatoons", are oval or pear-shaped and hold a few seeds in their center (Figure 3.5). *Amelanchier alnifolia* fruits are almost black while *A. bartramiana* fruits are dark purple.

Their fruit develop throughout June and mature in July. They attain maturity 45 to 60 days after flowering.

Ripe fruits have a dark purple/blue color, an important characteristic of quality due to the presence of anthocyanins, a type of polyphenol which contributes in the prevention of human diseases (Appendix 1). Fruits are also rich in iron and copper and are a good source of fibre (Ozga *et al.* 2006).

A B

Figure 3.5: Serviceberry fruits. Photos:
A) http://www.springvalleyroses.com/catalog/amelanchier-regent.html;
B) http://www.wsu.edu/~lohr/wcl/shrubs/amelalni/wamaldes.html.

3.3. Cultural practices

3.3.1. Plants

Different *Amelanchier alnifolia* cultivars have been developed in the Prairies and in the United States (Stang 1990, St-Pierre 1997). We can also find them in nurseries in Quebec, but we remind you that this species is poorly adapted for plantations in peatlands.

The *Institut de recherche et de développement en agroenvironnement* [Institute of Research and Development in Agroecology] (IRDA) conducted field trials with the *Amelanchier bartramiana*, and their results are promising. In fact, seedlings could be available soon (H. Rousseau, IRDA, pers. comm.).

3.3.2. Planting

3.3.2.1. Soil

Serviceberry prefers acidic or neutral soils; therefore, no lime treatment is necessary. However, they require moist but unsaturated soils.

3.3.2.2. Period

It is recommended to plant serviceberries early in the season, after the site is drained of the water from snow melt, but before the heat of summer.

3.3.2.3. Method

When it's time to plant, it is recommended to install black polyethylene mulch in order to enable the establishement of seedlings (substantial increase of growth rate; Clément-Mathieu 2004a; PERG, unpublished data) while greatly reducing weed infestation (see section 3.3.5. Weed control).

3.3.2.4. Spacing

Spacing between rows depends on the harvesting method. It varies from 3.5 m (manual and u-pick harvest) to 6 m (mechanical harvest). Spacing between seedlings can vary from 1 to 1.5 m. Narrow spacing between seedlings accelerates the development of a full hedge. We recommend wide spacing between rows in order to facilitate future mechanical harvest.

3.3.3. Soil moisture regime

Natural precipitations usually satisfy cultivation needs. However, irrigation can be essential during periods of drought, particularly during the preparation of the orchard and during the fructification period (St-Pierre 1997). Proper soil drainage and air circulation for the plants, as well as protection against frost, are important factors to consider for serviceberry orchards.

3.3.4. Fertilization

During trials conducted by the Peatland Ecology Research Group in Saint-Bonaventure peatland, *Amelanchier alnifolia* had a very poor growth and didn't respond to either different doses (0, 131.2 and 262.4 g/seedling of 1,7-9,4-14,4) or different methods of fertilization (injected in soil or at the surface; Clément-Mathieu 2004a, PERG, unpublished data). Therefore, it's impossible for the moment to make recommendations for fertilization of this species in cutover peatlands.

In the case of *Amelanchier alnifolia*, St-Pierre (1997) offers different recommendations. Firstly, an initial fertilization is advocated depending on the level of soil fertility. Afterwards, the choice for fertilization involves annual analysis of flowers and soil, as well as careful monitoring of shrubs, in order to detect and correct any deficiency or toxicity. When fertilization is required, it should be done in two applications; one in spring when buds are opening, and one at the beginning of June, after flowers have shed their petals.

3.3.5. Weed control

It's important to apply a certain weed control, particularly during the first years after planting, because serviceberry is sensitive to competition from other species (St-Pierre 1997; PERG, unpublished data).

Since the use of pesticides can be very problematic in cutover peatlands due to the risk of contamination of nearby fields where peat is stil harvested, it is recommended to use black polyethylene mulch to counter weed infestations while enabling the establishment and growth of serviceberry seedlings (Figure 3.6). However, it's important to note that application of plastic mulch requires specialized equipment (anticipate costs) and initial fertilization must done before mulch application (incorporation into the soil) or by fertirrigation (fertilization technique where the fertilizer is mixed into irrigation water).

Although, no clear recommendations were formulated in regards to fertilization, note that fertilizing at the surface can cause weed infestations if plastic mulch isn't used. Therefore, when planting, the injection of fertilizer into the soil is a good way to reduce weed infestations.

Regardless of the cultural technique used, mechanical or manual weeding of plantations is essential.

Figure 3.6: *Amelanchier alnifolia* planted in May 2004 and photographed in August 2004 in Saint-Bonaventure (Quebec). Photo: Stéphanie Boudreau.

3.3.6. Protection against the cold

Plantations in the Prairies showed that *Amelanchier alnifolia* requires the protection of a windbreaker in order to grow properly (St-Pierre 1997). The windbreaker must reduce wind velocity and offer winter protection to the plantation by increasing snow accumulation. Protection against frost, proper air circulation for the seedlings and proper soil drainage are among the most important factors to consider in serviceberry orchards.

3.3.7. Diseases and pests

In the Prairies, *Amelanchier alnifolia* is threatened by many different insects (St-Pierre 1997). In the event of an infestation, the producer must vaporise with an insecticide. No data is available for the *Amelanchier bartramiana*, but we believe that this species is less susceptible to pests.

Damages resulting from plant or fruit diseases must be well monitored when cultivating serviceberry. Limited availability of fungicides makes the fight against diseases difficult. Cultural practices such as trimming, improving air circulation and strengthening plant vitality, are often the only solutions available to producers against diseases and pests. Various diseases are described in the resources cited below.

Like for other fruit plantations, birds can cause problems. A certain number of devices exist on the market to scare away from the orchard birds and other intruders such as deers which like to graze on young branches. Certain producers use anti-birds nets to protect their berries.

3.3.8. Orchard maintenance and rejuvenation

According to knowledge acquired from the Prairies (St-Pierre 1997), we suggest regular trimming in order to keep the shrub vigorous, new shoots produce more fruits of better quality. The aim of trimming is to maintain a balance between younger and older branches allowing proper air circulation and elimination of low, sick, weak or dead branches.

Trimming begins during the third or fourth year, continues annually (or more often if diseases or damages justify it) and becomes more important when orchards achieve maturity after six to ten years.

3.3.9. Cultivation monitoring

Like it's the case for other types of culture, adequate monitoring is an essential tool to efficiently manage a serviceberry orchard (see Appendix 2 for a list of information that should be catalogued and preserved).

Suggested benchmarks for serviceberries are: survival, height, crown diameter, fruit yield and average size of fruits.

3.4. Fruits

3.4.1. Harvest

3.4.1.1. Method

To this day, the harvest of small pears is mainly done manually. Mechanical harvest is presently used in the Prairies with the help of specially-made pickers (very expensive because of their uniqueness and limited supply).

3.4.1.2. Period

The small pear is usually ready for harvest between the beginning and the end of July. Harvest time also depends on the final use of fruits. Fruits for transformation must be harvested in premature state in order to maintain their high levels of pectin and acid. Fruits bound for the fresh market must be harvested when they are more mature in order to benefit from a high level of sugar. The average number of days required for the proportion of mature fruits to go from 10% to 90% is 13.8 days (St-Pierre *et al.* 2005).

3.4.1.3. Orchard productivity

Serviceberries start producing fruits after three to five years. It produces important yields after six to eight years (if it is well-maintained) and achieves maximal yield after twelve to fifteen years. Serviceberry orchards can be productive for thirty to fifty years if they are well-maintained.

3.4.1.4. Yield

Fruit yield for a mature orchard can reach an average of 3 000 to 4 500 kg/ha (3 000 to 4 000 pounds/acre) in irrigated soil, representing 2 to 3 kg/plant (St-Pierre 1997; Table 3.1). However, production of fruits may be null if the flowers are lost due to late spring frost. Over a ten-year period in the life of a productive serviceberry orchard, it is reasonable to expect seven average harvests, two harvests showing a deficit and one above-average harvest.

3.4.2. Preservation

Since fruit quality decreases rapidly after harvest, they must be handled with care and cooled as soon as possible.

Table 3.1: Examples of *Amelanchier alnifolia* performance in cutover peatlands (Saint-Bonaventure, Quebec) or reported in the literature.

Source		Age	Survival (%)	Height (cm)	Growth (cm/year)	Yield (kg/ plant)
Clément-Mathieu (2004a)	With mulch	1 year	96	22	6	–
Clément-Mathieu (2004a)	Without mulch	1 year	96	15	1	–
PERG (unpublished data)	With mulch	2 years	66	55	29	–
PERG (unpublished data)	Without mulch	2 years	45	18	7	–
Zatylny *et al.* (2002)	15 cultivars	2 -7 years	–	–	20-40	–
St-Pierre *et al.* (2005)	15 cultivars	8 - 12 years	–	–	10-21	0.72 - 4.16
St-Pierre (1997)	–	–	–	–	–	2 - 3
Technical file from the *Union des producteurs agricoles* and the Government of Canada	–	Mature	–	–	450/ 10 years	–

3.4.3. Potential uses

3.4.3.1. Market

Serviceberry is mainly cultivated in Western Canada, where, for now, demand exceeds supply. However, we predict that the market will quickly saturate due to a great number of orchards reaching productive periods (Manitoba Agriculture, Food and Rural Initiatives 2006). The small pear is not well-known outside of the Prairies. Quebec only accounts for 0.5% of Canadian production (Catling and Small 2003). Therefore, markets have to be developed and consumers have to be informed if we want to increase production.

3.4.3.2. Use

The fruit called “small pear” or “Saskatoon” was an important source of food for First Nations and the first settlers (Manitoba Agriculture, Food and Rural Initiatives 2006). Today, small pear offers a large variety of uses such as the making of pies, jellies, syrup, ice creams, liquors and flavour concentrates, as well as bakery or wine. Fruits can be consumed fresh, frozen and even dried (http://www.saskatoonberry.com/).

3.5. Conclusion

True expertise exists regarding *Amelanchier alnifolia* cultivation in the Prairies, but we have little information concerning serviceberry cultivation in Eastern Canada. Cultivation trials with different species of this genus are on-going in Quebec by the *Institut de recherche et de développement en agroenvironnement* [Institute of Research and Development in Agroecology] (H. Rousseau, IRDA, pers. comm.). A few local producers have also established small orchards. For example, there are fifteen producers, whose plantations take up to 10 ha, in the Lac-Saint-Jean region (Croisetière 2006).

It's impossible to know the agricultural potential of serviceberries in cutover peatlands. However, we know that the *Amelanchier alnifolia* is poorly adapted to this habitat. Other trials should be conducted favouring species or cultivars better suited to conditions found in this type of habitat, such as A*melanchier bartramiana*, a species naturally found in peatlands.

3.6. References

3.6.1. Useful resources

3.6.1.1. Key informants

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Telephone: 306-956-2840
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Web site: http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1181922497480&lang=e; http://pgrc3.agr.gc.ca/staff/stpierre_e.html

Raynald Drapeau (cultivation of the serviceberry outside peatlands)
Agriculture and Agri-Food Canada
1468, rue St-Cyrille
Normandin (Quebec) G8M 4K3
Telephone: 418-274-3378, station 229
Email: drapeaur@agr.gc.ca
Web site: http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1181935933582&lang=e

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Photo: ©Ted Bodner, in Miller and Miller (2005), taken from the USDA-NRCS PLANTS Database

Taken from: Britton and Brown (1913), in the USDA-NRCS PLANTS Database

Chapter 4:

The elderberry

by

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4.1. Introduction

Canadian elderberry (*Sambucus nigra* ssp. *canadensis* (L.) R. Bolli) is a shrub common to humid habitats of Quebec, notably in natural peatlands (Marie-Victorin 1995, Small *et al.* 2004). This species offers good productivity, has a good adaptation capacity and settles easily (USDA 2001).

Its fruits are particularly popular for pies, jellies and jams. Recently, its small black fruits are generating new interest for high quality food colouring. The demand for elderberry fruits is such that harvests in natural habitats cannot meet demand. Agriculture and Agri-Food Canada (AAC) researchers have initiated a research program in order to determine essential factors to manage Canadian elderberry production (Charlebois and Richer 2005).

Canadian elderberry could be an interesting species to plant in cutover peatlands, as stated in a plantation study conducted at a Saint-Bonaventure site in Quebec (Fafard & Frères ltée) since 2004. Three years after planting, elderberry has displayed excellent survival rates, as well as good growth rates when fertilizer and black plastic mulch were used. A monitoring of this plantation over the next few years will help validate if elderberry can produce large fruit yields in cutover peatlands.

4.2. Species biology

4.2.1. Names

- *Sambucus nigra* ssp. *canadensis* (L.) R. Bolli

  Synonyms: *Sambucus canadensis* L., *Sambucus canadensis* var. *laciniata* Gray, *Sambucus mexicana* K. Presl ex DC., *Sambucus orbiculata* Greene, *Sambucus simpsonii* Rehd. ex Sarg., *Sambucus canadensis* var. *submollis* Rehd., *Sambucus cerulea* var. *mexicana* (K. Presl ex DC.) L. Benson

  Vernacular names:

  English: Canadian elderberry, American black elderberry, blackberry elder, Mexican elderberry, blue elder, common elderberry
  French: *sureau blanc, sureau du Canada*

  Family: Caprifoliaceae

4.2.2. Distribution and habitat

The *Sambucus* genus includes a dozen of species distributed in temperate regions (Small *et al.* 2004). The common elderberry, *S. nigra* ssp. *nigra*, is largely cultivated in Europe, in Northern Africa and in Western Asia. The Canadian elderberry originated in North Western North America (Figure 4.1). It can be found from Nova Scotia to Southern Florida and toward Western Manitoba.

In natural habitats, Canadian elderberry is found in various locations but prefers semi-open areas. These habitats include forest edges, roadsides, brooks, marshes, swamps and peatlands borders (Small *et al.* 2004).

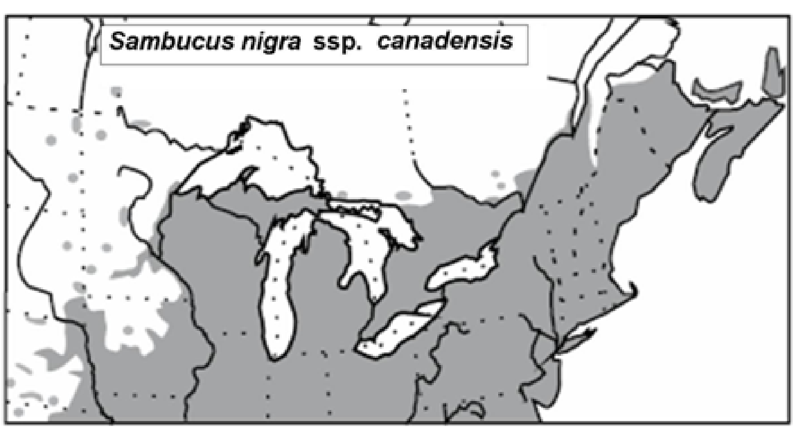

Figure 4.1: Distribution map (in grey) of the *Sambucus nigra* ssp. *canadensis* in North Eastern North America (exerpted from Small *et al.* 2004).

4.2.3. Plant characteristics

4.2.3.1. Vegetative parts

Canadian elderberry is a bushy shrub measuring 1 to 4 m in height, possessing multiple stems. It's spread out and often forms thick brakes[1] because of its root suckers (Marie-Victorin 1995). Its deciduous leaves, opposed and pinnately compound, have 5 to 11 lanceolated leaflets with lightly serrated edges (Figure 4.2). The stems, poorly branched and weakly ligneous, contain abundant marrow and start at the base (form root suckers). The plant is stoloniferous, and its root system is superficial (Smart *et al.* 2004).

Figure 4.2: Canadian elderberry leaves. Photo: Robert H. Mohlenbrock, 1989, from the USDA-NRCS PLANTS Database (2007).

4.2.3.2. Flowers

Canadian elderberry is magnificent when it blooms in June and July (Figure 4.3). Its late flowering distinguishes it from other elderberry species; their flowering process coincides with the development of their leaves (Marie-Victorin 1995).

Flowers are held in large umbels, which are larger than they are long, and can reach 40 cm. Each umbel may contain hundreds of creamy-white coloured aromatic flowers. Flowering of the inflorescences occurs over several weeks, and the flowering inside the same umbel is slightly unsynchronized.

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[1] Brakes: dense bush zones

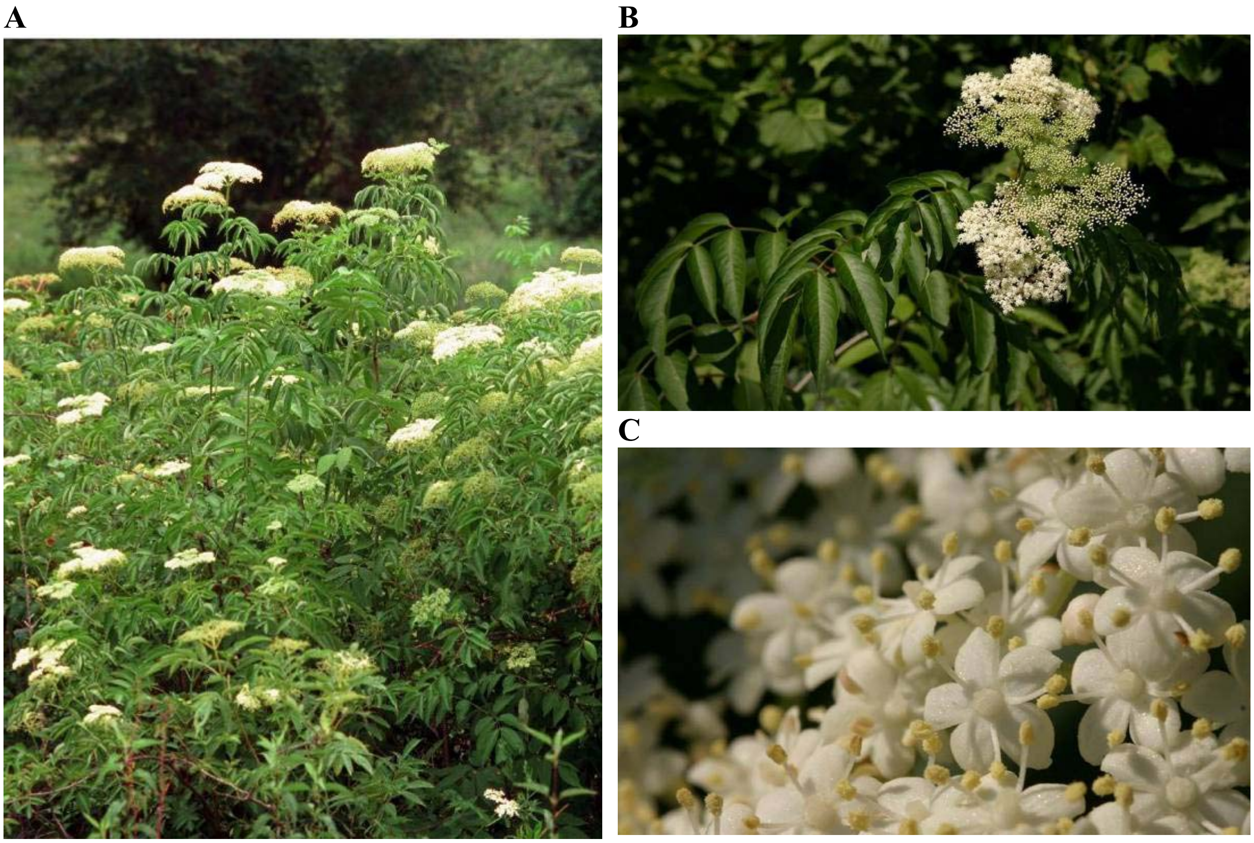

Figure 4.3: Flowers and inflorescences of the Canadian elderberry. All photos were taken from the USDA-NRCS PLANTS Database (2007): A) ©James H. Miller, in Miller and Miller (2005); B) and C) ©Patrick J. Alexander.

4.2.3.3. Fruits

Fruits produced by indigenous plants, small berries ranging from 5 to 6 mm in diameter, change from light green to red, and finally turn blackish purple-blue when mature (Figure 4.4). They contain high levels of anthocyanins. Therefore they have antioxidant proprieties (Appendix 1).

A

B

Figure 4.4: Immature (A) and mature (B) Canadian elderberry fruits. Photos: Gilles Ayotte.

4.2.4. Factors affecting yield

Care given during the establishement year is a key element to successfully cultivate this species. According to Charlebois and Richer (2006a), the elements which require particular attention are the following:

- type and quality of cuttings;
- good drainage;
- plot maintenance and use of mulch because young seedlings compete poorly against weeds.

4.3. Cultural practices

4.3.1. Plants

It's possible to produce your own seedlings in containers by using cuttings of healthy and vigorous plants taken in sites from the same region as the site to be restored. However, it can be advantageous to buy particular cultivars, depending on the intended use of the fruits. If targeting fruit production, a mix of two productive cultivars should be considered as a measure of precaution (Charlebois and Richer 2006a).

The choice of cuttings is important as healthy cuttings guarantee good survival rates. The chances of recovery are usually better with older seedlings (1 to 2 years) than with fresh cuttings, but the former are more costly.

So far, trials conducted in cutover peatlands were done using seedlings in 110 cc containers (Clément-Mathieu 2004).

4.3.2. Planting

Site preparation is an important factor for successful establishement. Although elderberry isn't a demanding species, the site should fulfil its basic needs to insure establishement and growth of seedlings. Adequate drainage combined with a substrate having good water retention is essential.

Canadian elderberry generally grows well when pH is between 5.5 and 7.5 (Small *et al.* 2004). However, it performed well at Saint-Bonaventure peatland where pH is just below 4.0 (Clément-Mathieu 2004). Nevertheless, we could expect low yield because elderberries planted in poor acidic soils (pH of 4.7) produce fewer umbrels and fruits (Wazbinska and Puzcel 2002). Moreover, Charlebois and Richer (2006a) suggest adjusting pH level (liming) before the planting process.

We suggest planting the cuttings in spring, after site is drained of water from the snow melt, sufficiently deep to avoid unearthing (this problem is generally associated with multi-cell cuttings).

Recommended distance between plants is 2 m and between rows is 4 m. However, recent studies tend to slightly reduce these distances to be more profitable. It's important to keep in mind available equipment for maintenance of aisles when choosing distance between rows.

4.3.3. Soil moisture regime

Canadian elderberry tolerates a large variety of drainage regimes, from drought to poorly drained soil (Gilman and Watson 1994). This flexibility is ideal for planting in cutover peatlands because soil is usually dry in the summer, but each season, several soil saturation episodes can be observed.

However, Charlebois and Richer (2006b) suggest giving particular attention to the maintenance of drainage systems because poor drainage in spring can have disastrous consequences if a frost and defrost cycle occurs. In order to increase elderberry fruit size and yield, irrigation should be considered where annual precipitations are lower than 700 mm (AAC 2003).

4.3.4. Fertilization

It is necessary to fertilize elderberry in order to obtain good growth in cutover peatlands. Currently, the best tested fertilization regime for this species in cutover peatlands (Saint-Bonaventure) is 130 g/plant of 1.7-9.4-14.4[2], applied during plantation process.

If mulch isn't used (see section 4.3.5. Weed control), this dose should be buried in order to minimize potential invasion of competitive species (for each seedling, split the dose into two holes, 5 cm in depth, located roughly 10 cm from the seedling).

However, studies must be carried out in order to pinpoint the best doses and formulation for Canadian elderberry. Roper *et al.* (1998) mentioned the need to apply nitrogen annually either in the form of urea, ammonium sulphate or ammonium nitrate to enhance Canadian elderberry's vegetative growth. As for the other berries, repetitive fertilization should be tested in order to improve yield.

4.3.5. Weed control

Presence of competitive species is generally harmful to survival and growth of Canadian elderberry (AAC 2003). Therefore, maintaining plots is essential for the establishement and growth of seedlings, and the battle against weeds is necessary during the first three to five years. Plastic mulch and regular weeding are two options in controlling infestation of competitive species. The use of black polyethylene reduces weeds in addition to helping elderberry's growth, but appropriate machinery is needed for its installation. As for mechanical weeding (plan for two to three cutings per year), it can be done with a lawn tractor or another type of machinery if rows are spaced sufficiently. However, this can require quite some time.

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[2] N-P_2O_5-K_2O

Figure 4.5: Canadian elderberry planted at Saint-Bonaventure peatland in spring of 2004 with black plastic mulch. Photo: PERG, August 2004.

4.3.6. Diseases and pests

Few insects seem to threaten elderberry. The fall webworm was identified as a source of potential problems, but its identification and control isn't problematic. The presence of elderberry borer can also cause damage to plantations. However, proper oversight of the plantation should make it easier control borers (Charlebois and Richer 2006a).

Important losses can be caused by the presence of deers, groundhogs, hares and other mammals (Figure 4.6). Birds can also be a source for substantial losses. Detonators and alarms, harvesting fruits as soon as they are mature and, most importantly, installing nets, are methods which may help to counteract these pests.

4.3.7. Field maintenance and rejuvenation

It's important to prune shrubs early in the growing season in order to promote vigorous sprouts, to remove stems damaged by winter and to improve fruit production.

Figure 4.6: Damages caused by deer grazing. Photo: S. Boudreau, May 2007.

4.3.8. Cultivation monitoring

Like it's the case for other cultures, adequate follow-up is an essential tool to efficiently manage an elderberry plantation (see Appendix 2 for a list of information that should be catalogued and preserved).

Suggested measures for this species are: survival, height, crown diameter, fruit yield and average size of fruits.

Table 3.1: Canadian elderberry survival and height, three years after plantation at Saint-Bonaventure (Quebec) peatland, with or without plastic mulch, and with initial fertilization (262.4 g of 1.7-9.4-14.4; PERG, unpublished data).

	Survival (%)	Height (cm)
With mulch	92	100
Without mulch	56	85

4.4. Fruits

4.4.1. Harvest

First harvest is to be planned as early as the second year of growth. Harvesting efforts should peak during the third or fourth year of growth (Charlebois and Richer 2006a).

Elderberry fruits take 5 to 15 days to mature, they are usually ready between mid-August and mid-September. Harvesting period should be spread over two weeks at the most. Harvest is easy and is similar to that of grapes.

4.4.2. Yield

Productivity varies depending on the cultivar, but it’s reasonable to reach a yield of 2 to 5 kg per plant.

4.4.3. Preservation

Depending on the eventual use of fruits, additional refrigeration and transportation costs must be anticipated. In fact, keeping fruits in containers at room temperature for more than 2 to 4 hours should be avoided; heat can decrease fruit quality, and they could spoil quickly.

4.4.4. Potential uses

Canadian elderberry can be used for its decorative qualities or its potential as a wind breaking edge. On small scales, foliage can be used for its medicinal properties and flowers as an ingredient for candy.

Elderberry is largely used to make extracts, syrups and supplements. Scientific literature supports many qualities attributed to elderberry. In the food industry, its fruits are used to make jellies, syrups, juices, beverages, wines, beers, fruit bars, etc. (Guilmette 2006).

Recently, these small black fruits have attracted new interest. In fact, Colarôme inc. has developed an extraction process for the making of high quality food colouring.

4.5. Conclusion

Elderberry is a very interesting species to consider when establishing plantations in peatlands due to a strong demand for its fruit and few requirements for the cultivation of this shrub. At Saint-Bonaventure site, unfertilized plants with no mulch cover performed poorly, hence underlining the importance of fertilizing and of continuing trials to reach optimal cultivation management in cutover peatlands.

4.6. References

4.6.1. Useful resources

4.6.1.1. Key informants

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Agriculture and Agri-Food Canada
430, boul. Gouin
Saint-Jean-sur-Richelieu (Quebec) J3B 3E6
Telephone: 450-515-2026
Email: charleboisd@agr.gc.ca
Web site: http://res2.agr.ca/stjean/

4.6.1.2. Documentation (primary sources of relevant information)

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Schooley, K. 2002. Elderberries for Home Gardens. Factsheet 95-005. Ministry of Agriculture, Food and Rural Affairs of Ontario 6 p. Available online at http://www.omafra.gov.on.ca/english/crops/facts/95-005.htm

4.6.1.3. Web sites

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Photo: Gilles Ayotte

Chapter 5:

The cranberry

by

Guillaume Théroux Rancourt

Photo: Gilles Ayotte

Photo: http://www.jus-canneberge.com/galerie.php

5.1. Introduction

Cranberry is an economically interesting fruit widely-cultivated in North America. Interest for this plant has increased over the past few years in part because of its high levels of antioxidant (Appendix 1) and its health benefits for problems such as urinary tract infections (Cranberry Institute 2007). The United States cultivates roughly 90% of the world production, Canada being far behind in second position (FAO 2006). Between 15 to 20% of cultivated areas are located on peat soil, but no commercial plantations exist in abandoned peatland.

This chapter will briefly present the cranberry, its cultivation, as well as different cultivation projects in peatlands. Consequently, we'll mostly discuss of one specific species: *Vaccinium macrocarpon*. Given the expertise available in different ministries, we will not linger on details pertaining to cranberry cultivation requirements.

5.2. Species biology

5.2.1. Names

Cranberries are part of the Ericaceae family. Two species are found in peatlands and produce edible fruits:

- *Vaccinium macrocarpon* Ait. (cultivated species; Figure 5.1A)

  Synonym: *Oxycoccus macrocarpus* (Ait.) Pursh

  Vernacular names:

  English: large cranberry
  French: *airelle à gros fruits, canneberge, gros atocas*

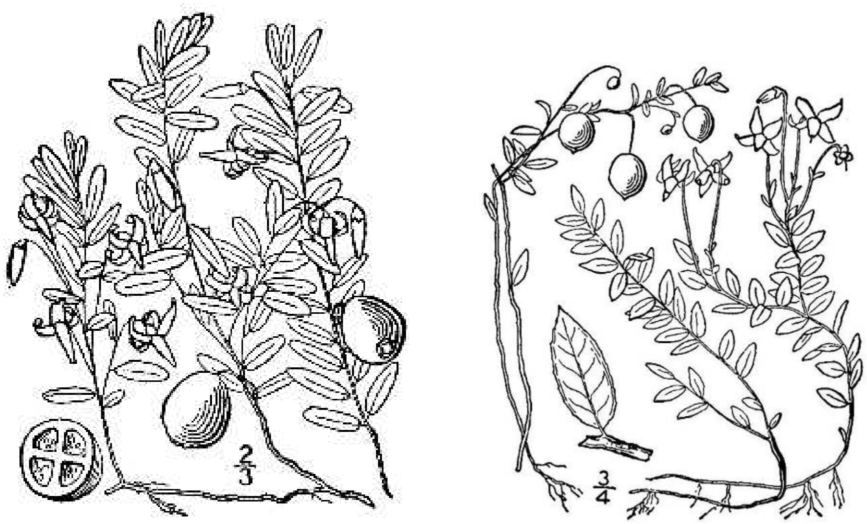
- *Vaccinium oxycoccos* L. (Figure 5.1B)

  Synonyms (amoung others): *Oxycoccus microcarpos* Turcz. ex Rupr., *Oxycoccus oxycoccos* (L.) Adolphi, *Oxycoccus palustris* Pers., *Vaccinium microcarpos* (Turcz. ex Rupr.) Schmalh., *Vaccinium palustre* Salisb.

  Vernacular names:

  English: small cranberry
  French: *airelle canneberge, petite canneberge, atocas*

Current cranberry varieties available for cultivation are the results of repeated crossings of selected *V. macrocarpon* plants (Agriculture Canada 1982). Another species very similar to the cranberry is the lingonberry (see section 7.2).



A **B**

Figure 5.1: A) *Vaccinium macrocarpon* Ait. and B) *Vaccinium oxycoccos* L. Images taken from: Britton and Brown (1913), in the USDA-NRCS PLANTS Database (2007).

5.2.2. Distribution and habitat

Vaccinium macrocarpon is a species which grows, in Canada, from Newfoundland to Manitoba, as well as in North Eastern United States (Gleason and Cronquist 1991, Natural Resources Canada 2007). *Vaccinium oxycoccos* is, on the other hand, a circumboreal species (Gleason and Cronquist 1991, Marie-Victorin 1995).

Cranberry is usually found in habitats well-supplied in water, but not flooded, because its growth requires aerated soils (Trehane 2004).

It is found in acidic soils with pH levels ranging between 3.5 and 5.5. It grows on peat soils, often in *Sphagnum* peat, but also grows well in acidic mineral soils, such as sand (Trehane 2004). Adding organic material to the sand may be necessary to make it suitable for cranberry cultivation.

5.2.3. Plant characteristics

The commercially-valuable cranberry, *V. macrocarpon*, is a peatland plant possessing crawling woody stems from which emerge roots and aerial roots that hold flowers and fruits (Figure 5.2; Parent 2001, Trehane 2004). At the end of summer, floral buds form at the extremity of the sprouts. Flowers bloom and produce fruits the following year. Flowers open mid-July at which time insects pollinate them. Fruits reach maturity at the end of October; the exact date depends on the variety, the season and the geographic location.

A B

Figure 5.2: A) *Vaccinium oxycoccos* flowers in a natural peatland and B) *Vaccinium macrocarpon* in fruits, in a natural peatland. Photos: Gilles Ayotte.

5.3. Cultural practices

This section is not a guide for cranberry production. Many works explore this subject in depth (see reference section). This section briefly presents primary cultural techniques, as well as cultivation in peatlands.

5.3.1. Historical background of cultivation

Currently, cranberry is not mainly cultivated in peatlands. However, historically, peatlands were areas of predilection for its cultivation. Cranberry cultivation has apparently begun at the beginning of the 19th century in Massachusetts, in Cape Cod area (Eck 1990). Henry Hall, a veteran of the American revolutionary war, observed that cranberry plants partially covered with sand had a more vigorous growth and a more abundant fruits production. This technique, using sand, discovered fortuitously, is now a key step in cranberry production.

Originally, cultivation areas were often ombrotrophic peatlands, modified in order to cultivate cranberries. Because of numerous rules and laws enacted for the protection of territories and the environment, it's now hard to start cultivation of cranberries in these areas. In addition, it is necessary to have different permits in order to supply water to the cranberry field.

In Quebec, cranberry cultivation began in 1939 in a peatland located near Drummondville (Bureau 1970). This type of production has risen rapidly over the last twenty years.

5.3.2. Primary cultural practices

In Quebec, the technique named from Wisconsin, developed in this Amercian state, is used. This technique is the most used cultivation technique in recent cranberry plantations. It involves major modifications of the habitat and requires an initial investment ranging between 75 000 and $110 000/ha. Sites having substantial proportions of sand are usually chosen. They are often located near a peatland, which can be a good source of water supply. The environment is greatly modified when beginning cultivation: cultivation fields are dug, trenches and dams are shaped, a water reservoir is created and a system to control the water level is laid out.

Significant water supply – between 10 000 and 20 000 m^3 of water/ha per year, according to water renewal in reservoirs – is essential. Water protects spring flowers from frost, irrigates during summer, prevents fruits from freezing in autumn and helps for winter flooding (flooding of cranberry fields creates a layer of ice that will settle on plants protecting them against hardships of winter). In order to have sufficient water supply, this requires a drainage reservoir five to seven times larger than the cultivation area. However, environmental authorisations may be required in order to pump water from watercourses (J. Painchaud, MAPAQ, pers. comm.).

In addition, sand is abundantly used during the planting process in order to create a suitable environment for the seedlings to take root. Otherwise, sand is mainly used for maintenance consisting in the addition of 3 to 4 cm of sand every three years in order to improve conditions for seedlings to take root. This step is done during winter, on the layer of ice covering the cranberry field.

Modern cultivation of cranberry requires major site modifications. This implies important engineering undertakings and should be considered before embarking upon the cultivation of this fruit.

5.3.2.1. Cultural practices in peatland

Few specific recommendations were issued regarding the cultivation of cranberry in peatlands. Plantations in peatlands are generally conceived like those in mineral soils, but certain aspects have to be taken into account. It's not recommended to plant in poorly drained peat because it limits the growth of seedling roots (Eck 1990). It's usually recommended to use peat with a decomposition degree lower than H6 on the von Post scale (J. Painchaud, MAPAQ, pers. comm.). It's very important to control drainage, and this can be more difficult in poorly drained peat soils.

Width of cultivation fields on peat soils is 37 m (120'), and it is so to facilitate the installation of sprinklers, which are not permanently installed in the field, being more favourable to breaches and less stable than in mineral soils.

It's not recommended to plant cranberry in recently cleared peatlands due to the peat's rapid decomposition in the first years of exposure (Eck 1990). There is also a risk of losing seedlings due to frost heaving when they are planted directly in peat, mostly during the first years following planting.

When planting, it's important to set a layer of coarse sand on the cultivation field in order to help root taking. This will stimulate stem formation, which is particularly important in peat soils (J. Painchaud, MAPAQ, pers. comm.).

Generally, it's harder to achieve exceptional yields in peatlands. However, with proper management, it's possible to achieve average yields (see section *Production in peatland of Canada*). Furthermore, they are more buffered habitats than sandy soils. In fact, it is easier to overcome errors or deficiencies in the later than in sandy soils, such as an excessive renewal cutting, a lack of water or deficient fertilization. Nevertheless, the reverse effect is also true: it's harder to achieve record yields, because these successes are also buffered. In addition, nitrogen fertilization is normally less important in peatland due, among other things, to mineralization of nitrogen (in Quebec, 20 units of nitrogen instead of 40; J. Painchaud, MAPAQ, pers. comm.). However, if there is excess water during summer, it could be problematic, especially when drainage is deficient.

5.3.2.2. Production in Canadian peatlands

We estimate that in Quebec, approximately 20% (176 ha) of all cranberries are planted in peat soils (Association des Producteurs de Canneberges du Québec, 2004, pers. comm.). They are found almost everywhere in Quebec. However, many plantations are established on the outskirts of peatlands. In Quebec, in the *Centre-du-Québec* region, average yields range between 22 500 to

27 000 kg/ha. Average yields in peatlands are between 21 300 and 22 400 kg/ha (J. Painchaud, MAPAQ, comm. pers.).

Cranberries have been planteds in the Côte-Nord region, at Les Escoumins. This plantation was established on a shallow part of the peatland (less than 1 m), where surface vegetation was removed, and field was re-shaped, particularly, by inserting three drains per cultivation field (C. Imbeault, Tourbière Lambert inc., pers. comm.). An area of approximately 6 ha is in production since 1992, and this area will increase to 14 ha in the next years, all of it for organic production. Thanks to its northern location – *Centre-du-Québec* being the main cranberry production region in Quebec – this plantation achieved interesting results with regards to fruit quality which contains a lot of anthocyanins, cranberry's main antioxidant and pigment responsible for its red colour. In this particular peatland, anthocyanins ratio is over 70 mg/100 g of fruit. Usually, harvest is done when anthocyanins ratio surpasses 30 mg/100 g of fruit, the average of harvested fruits reaches approximately 34 mg/100 g of fruit (Appendix 1). Thus, fruits harvested in this peatland are of better quality.

However, cranberry yield obtained at Les Escoumins (15 700 kg/ha; J. Painchaud, pers. comm.) is lower than averages reached in *Centre-du-Québec* (22 500 to 27 000 kg/ha). Still, the plantation generates some profits since it is under organic management. Nevertheless, since profits began to go up, there are now more investments in this type of production, notably in the purchase of specialized equipment, which could improve production management.

In New Brunswick, approximately 15% of plantations (two established and one in preparation) are based in peatlands, mainly in Gloucester and Kent counties (G. Chiasson, Department of Agriculture and Aquaculture, New Brunswick, pers. comm.).

5.3.2.3. Planting in cutover peatlands

Cranberry cultivation experiments were conducted in cutover peatlands, but no commercial plantations exist to this day. Trials were conducted in New Brunswick (G. Chiasson, Department of Agriculture and Aquaculture, New Brunswick, pers. comm.). Width of the cultivation fields was 45 m (150'), a width usually encountered in sandy soils. Seedlings were directly planted in peat, whereas, normally a light layer of sand is added. Plant production was good, except at the center of the field. In this area, drainage was deficient because the field was too large. Since, drainage has been improved in this area.

In Estonia, cranberries were also planted within a goal of reclamation in a cutover peatland (Noormets 2006). On the studied peatland, cranberry implantation helped favour the establishment of plants typically found in peatlands, such as *Polytrichum*.

In Finland, a project is ongoing with local farmers in order to favour implantation of cranberries (Kainuu Rural Advisory Centre *et al.* 2006). The species used, *Vaccinium oxycoccos*, is a smaller species than the one cultivated in North America, *V. macrocarpon*. In this project, planting will take place in peatlands owned by farmers. The targeted scale is much smaller than productions in Canada. The goal is more to improve a natural habitat or to practice cultivation on a recently cleared peatland than to develop a very intensive cultural system. One producer has been cultivating the North American species for many years, but yields are very low.

5.4. Conclusion

Cranberry production has already been used for reclamations in cutover peatlands. However, it's important to remember that production according to current methods in North America requires a significant initial investment. Furthermore, fruit prices are low at the moment, which makes it harder to rapidly implement a profitable cranberry field. It's also more difficult to implement a cranberry field in peat soil, that's why the majority of producers prefer to plant in sandy soil.

Before establishing a cranberry field in cutover peatlands, it is recommended to consult a specialist in cranberry production. However, it's important to remember that the key factor in a successful cranberry plantation in peatland is drainage of cultivation fields in order to improve growth.

5.5. References

5.5.1. Useful resources

5.5.1.1. Key informants in Canada

Quebec

Jacques Painchaud, agr.
Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec,
Centre de services de Drummondville
750, boul. René-Lévesque, bureau 101
Drummondville (Quebec) J2C 7N7
Telephone: 819-475-8403
Email: jacques.painchaud@mapaq.gouv.qc.ca

L'association des producteurs de canneberges du Québec (APCQ)
2700, av. Vallée
Plessisville (Quebec) G6L 2Y6
Telephone: 819-621-0034
Email: apcq@cetaq.qc.ca
Web site:
http://www.producteurscanneberge.com/

New Brunswick

Roger Tremblay, agr.
New Brunswick Department of Agriculture and Aquaculture
Agriculture research station (experimental farm)
C.P. 6000
Fredericton (New Brunswick) E3B 5H1
Telephone: 506-453-3475
Email: roger.tremblay@gnb.ca

5.5.1.2. Documentation

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5.5.1.3. Web sites

Berry sections of the AgriRéseau Web site (contains a section on biological cultivation): http://www.agrireseau.qc.ca/petitsfruits/

Department of Agriculture and Aquaculture, New-Brunswick – Cranberry site selection: http://www.gnb.ca/0171/20/0171200011-e.asp

Le centre d'interprétation de la canneberge: http://www.canneberge.qc.ca/canneberge.html

The American cranberry (directory of Web sites and online documents on different subjects related to the cranberry and its production): http://www.library.wisc.edu/guides/agnic/cranberry/cranhome.html

Cape Cod cranberry Growers' Association (the oldest cranberry producers association in North America): http://www.cranberries.org/

The cranberry Institute (information on the health benefits of cranberry): http://www.cranberryinstitute.org/

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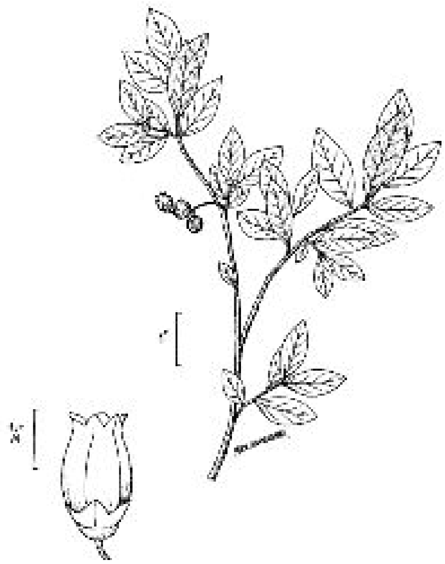
Noormets, M. 2006. Some aspects of flower biology of lowbush blueberry (*Vaccinium angustifolium* Ait.) and velvet-leaf blueberry (*V. myrtilloides* Michx.); Cultural management of lowbush blueberry and cranberry (*Oxycoccus palustris* Pers.) on exhausted milled peat areas, in Institute of Agricultural and Environmental Sciences. Estonian University of Life Sciences, Tartu. 165 pp.

Parent. L.-É. 2001. L'utilisation agricole. Pp. 411-421 in S. Payette & L. Rochefort (eds.). Écologie des tourbières du Québec-Labrador. Les Presses de l'Université Laval, Sainte-Foy, Quebec.

Trehane, J. 2004. Blueberries, cranberries and other *Vaccinium*. Portland and Cambridge, Timber Press. 256 pp.

United States Department of Agriculture (USDA). 2007. USDA-NRCS PLANTS Database. Available online at http://plants.usda.gov/index.html. Consulted in May 2007.



Taken from the: USDA NRCS (Wetland flora: Field office illustrated guide to plant species), in the USDA-NRCS PLANTS Database (2007)

Chapter 6:

The blueberry

by

Julie Bussières, Guillaume Théroux Rancourt, Line Lapointe, and Line Rochefort

Photo: Kenneth J. Sytsma, taken from http://www.botany.wisc.edu/herbarium/

6.1. Introduction

Canada is the number one wild blueberry producer in the world, with provinces of British Columbia (for the highbush blueberry), Nova Scotia, Quebec and New Brunswick as leading producers. Annual production has increased since late 1990's because of an enhancement of the productivity and the superficie of blueberry fields (MAPAQ 2005). Although blueberries grow naturally in peatlands, the majority of cultures are done in sandy soils by planting indigenous crops. Cultures can also be done by planting them on abandoned agricultural land or on ancient Jack Pine plantations, for example. This is the case in Saguenay-Lac-Saint-Jean, Abitibi and Côte-Nord regions. Exhaustive documentation is available on lowbush and highbush blueberries, pertaining to their biology, cultural management (conventional and organic), phytoprotection, harvests, etc. (consult section 6.5. References).

Some trials have been conducted in cutover peatlands, notably in Estonia, where researchers studied lowbush blueberry cultivation (Noormets *et al.* 2003), as well as in Quebec, where lowbush blueberries (2000) and highbush blueberries (2001) were tested at the Saint-Bonaventure peatland (Fafard & Frères ltée). At this site, lowbush blueberry plantations have been abandoned for different reasons but highbush blueberries are still being studied. In New Brunswick, promising highbush blueberry trials have been conducted by Thériault & Haché Peat Moss Ltd, during summer of 2006.

Given the expertise available in different ministries, we will not linger on details pertaining to blueberry cultivation requirements, but will offer an overview of general literature and available resources.

6.2. Species biology

6.2.1. Names

Blueberries are part of the Ericacea family. Here are the three main species cultivated for their berries:

- *Vaccinium angustifolium* Ait. (the most widespread blueberry species found in the wild; Figure 6.1A)

  Synonyms: *Vaccinium brittonii* Porter ex Bickn., *Vaccinium lamarckii* Camp, *Vaccinium nigrum* (Wood) Britt., *Vaccinium angustifolium* var. *hypolasium* Fern., *Vaccinium angustifolium* var. *laevifolium* House, *Vaccinium angustifolium* var. *nigrum* (Wood) Dole

  Vernacular names:

  English: lowbush blueberry
  French: *airelle à feuilles étroites, bleuet nain*

- *Vaccinium myrtilloides* Michx. (often mistaken for *V. angustifolium* and intercalated in production fields)

  Synonyms: *Cyanococcus canadensis* (Kalm ex A. Rich.) Rydb., *Vaccinium canadense* Kalm ex A. Rich., *Vaccinium angustifolium* var. *myrtilloides* (Michx.) House

  Vernacular names:

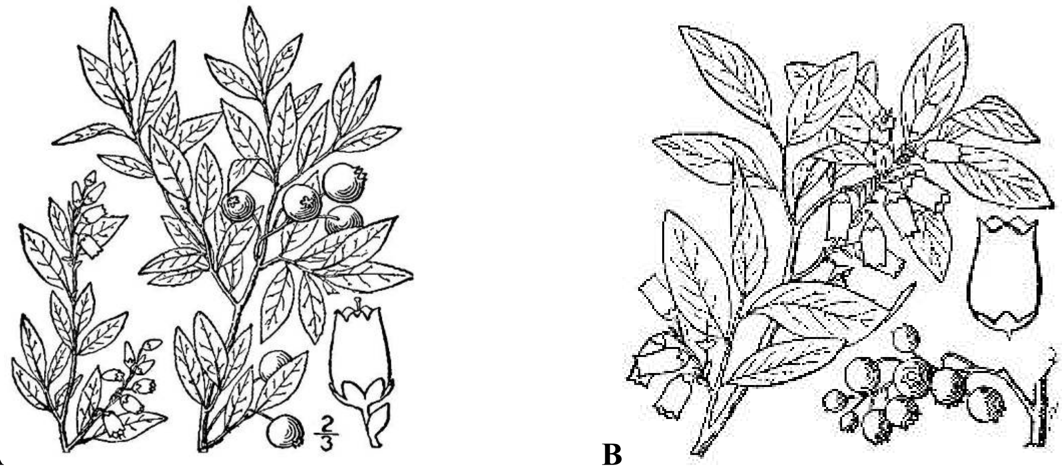
  English: blueberry, sour-top blueberry, velvetleaf huckleberry
  French: *airelle fausse-myrtille, bleuet nain*

- *Vaccinium corymbosum* L. (species often cultivated; Figure 6.1B)

  Synonyms: *Vaccinium constablaei* Gray, *Cyanococcus corymbosus* (L.) Rydb., *Cyanococcus cuthbertii* Small, *Vaccinium corymbosum* var. *albiflorum* (Hook.) Fern., *Vaccinium corymbosum* var. *glabrum* Gray

  Vernacular names:

  English: highbush blueberry, high blueberry
  French: *airelle en corymbe, bleuet en corymbe*



A B

Figure 6.1: A) *Vaccinium angustifolium* Ait. and B) *Vaccinium corymbosum* L. Images taken from: Britton and Brown (1913), in the USDA-NRCS PLANTS Database (2007).

6.2.2. Distribution and habitat

Vaccinium angustifolium and *V. myrtilloides* are generally found everywhere in Quebec, in humid habitats, acidic soils and peatlands. *V. myrtilloides* is often associated with rockier regions (Marie-Victorin 1995)

Vaccinium corymbosum reaches its northern limit in Southern Quebec, where winters are milder. Its height (it can reach heights of 2 m) keeps it from spreading north; its buds are too high off the ground to benefit from snow protection against freezing. It generally grows in Western and Central Quebec and it isn't normally found past Quebec City. In nature, highbush blueberry establishes in moist, acidic, peat soils in sunny areas, near water, on mountains, near ditches or in marshes.

6.2.3. Plant characteristics

Lowbush blueberry (Figure 6.2A) is a low plant reaching about 40 cm in height, whereas the highbush blueberry (Figure 6.3) has a shrubbier shape, each individual plant reaches 1 to 3 m in height. Blueberries lose their foliage during winter.

Vaccinium angustifolium is differentiated from *V. myrtilloides* by dense hairs found on its leaves and branches (Figure 6.2). Thus, it's said that *V. myrtilloides* is densely pubescent whereas *V. angustifolium* is rather glabrous.


A


B

Figure 6.2: A) *Vaccinium angustifolium*, rather glabrous and B) *Vaccinium myrtilloides,* very pubescent. Photos: Gilles Ayotte.


A


B

Figure 6.3: *Vaccinium corymbosum* flowers (A) and leaves (B). Photos: H. & M. Ling, taken from http://www.npsnj.org/vaccinium_corymbosum.htm.

Blueberries are blue, almost black, berries that reach maturity between the month of July and September. According to a study conducted by the Department of Agriculture of the United States, blueberries are among the richest fruits in antioxidants. Highbush blueberry, which isn't as rich as lowbush blueberry does, however, have high levels of anthocyanins, as most blueberry species (Appendix 1). Highbush blueberry is cultivated in the United States, where selections resulted in huge blueberries now found on the market. In Canada, 97% of all highbush blueberries are produced in British Columbia, which ranks it third in worldwide production (AAC 2003).

Figure 6.4: ***Vaccinium angustifolium*** **fruits. Photo: Allan G. Austin, taken from: http://nature.ca/plnt/popups/pop0008_f.cfm.**

6.3. Cultural practices

Many guides discuss cultural practices used for different blueberry species. A series of information sheets is available on the University of Maine Website, which has a wild blueberry cooperative research program (University of Maine Cooperative Extension 2007). The following section deals with specific practices used in cutover peatlands.

6.3.1. Plants

Since many species and subspecies of lowbush blueberries exist in natural peatlands, it would be beneficial to obtain or produce seedlings from strains found in peatlands of the same region as the cutover site being reclaimed.

6.3.2. Planting

For lowbush blueberry, recommended spacing between seedlings is 30 to 45 cm within a row and 110 to 130 cm between rows, for a density of 17 000 to 30 000 seedlings/ha. For highbush blueberry, spacing depends on the equipment used during operations such as fertilizing, cutting and controlling weeds; 1.2 to 1.5 m could be left between seedlings and 2.4 to 3 m between rows, depending on the width of machinery (CPVQ 1997).

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6.3.3. Fertilization

It should be noted that surface fertilization on a cutover peatlands can enable weed infestations which will require a certain control (see section 6.3.4. Weed control). Burying fertilizer during the planting process (as mentioned for the black chokeberry in section 2.3.4) could be an effective way of eliminating the risk of weed infestations during the highbush blueberry's first few growing seasons.

Experiments conducted in Estonia have shown that it's necessary to fertilize if a good blueberry (*V. angustifolium*) production is wanted in cutover peatlands (Noormets *et al.* 2003). Fertilizers tested were 10-20-20 and 0-12-18 with micro-elements, doses ranging between 126 to 252 kg/ha, were spread over the surface in spring following the planting year. Results from this study suggest that lower quantities would be sufficient for plantations in cutover peatlands and annual fertilization may not be necessary.

At Saint-Bonaventure peatland (Fafard & Frères ltée), a few lowbush blueberry plantations were established in cutover fields and fertilized with 610 kg/ha of 4-22-34 (SUL-PO-MAG). It seems that this dose was too strong or toxic for blueberries, because signs of burns and necrosis were noticed all over the plantation. Other than this observation, the survival rate recorded after two years was on average 75%. Since, lowbush blueberry plantations have been abandoned due to burned plants and weed infestations. Surviving plants are still on site, but since they are being reaped several times per year, it prevents fruit formation.

Highbush blueberry trials conducted at the same site didn't offer promising results and no recommendations can be put forward, for now, regarding fertilization of this species in cutover peatland.

6.3.4. Weed control

Weed control is a factor to consider before planting blueberries in cutover peatlands. Needed fertilization for blueberry plantations will favour vegetative infestation, sometimes of tall species, originating from farming or from acidic habitats. For different reasons, you can choose not to use herbicides to control weeds. In the case of lowbush blueberry, it's recommended to weed mechanically by hoeing the cultivated zone (CPVQ 1997, New Brunswick Department of Agriculture and Aquaculture 2007). Use of plastic mulch or mechanical weeding should be considered for highbush blueberry (Duval 2003). For example, weed can be cut using a lawn tractor (may require two or three cuts per year) if spacing between rows is sufficient (generally 3 m) or a typical weeding machine for this type of cultivation.

At Saint-Bonaventure peatland (Fafard & Frères ltée), a weed infestation, joined with the impossibility of using herbicides, forced the abandonment of lowbush blueberry plantations and the begining of new highbush blueberry plantation trials using mulch. These last trials didn't give promising results, and this cultivation is still subject to follow-ups (results are unavailable at the time being).

6.3.5. Windbreakers

The use of windbreaking hedges should be considered in peatland plantations in order to increase the accumulation of snow on blueberry plantations and reduce wind erosion in areas where peat is exposed. Currently, recommended species to serve as windbreakers in cutover peatlands are the black chokeberry (fruit shrubs measuring one to two meters in height), the black spruce and the tamarack.

6.3.6. Field rejuvenation

It's important to remember when establishing a blueberry field, that specialized equipment will be necessary for future operations, including: fertilizing, cutting, weeding and harvesting.

Cutting is an essential operation for a good blueberry field yield (Blatt *et al.* 1989, Lareau 1990, New Brunswick Department of Agriculture and Aquaculture 2007) it should be mechanical and non-thermal, considering the risk of fire in cutover peatlands.

Blueberry cutting is done in spring, after the big frosts. Cutting aim is to maintain plant vitality and productivity, to increase quality and caliber of fruit as well as to prevent diseases and pests (Reid 2006).

Highbush blueberry requires little cutting during the first three to four years. During this period it's only necessary to get rid of broken, sick or dead branches. In the following years, cutting will also include taking out unproductive stems and finding stems that receive little or no light consequently having late and low quality fructification. It is important to maintain plants with stems of different ages in order to insure stable and ongoing production (Reid 2006).

A curious fact about lowbush blueberries tested at Saint-Bonaventure peatland: formation of new seedlings by growing rhizomes (underground stems) has never been observed near mother-plants, and this, three years after planting (J. Bussières, pers. obs.). It will be interesting to see if other plantations in cutover peatlands can get denser in the future, such is usually the case for blueberry production in mineral soils.

6.4. Conclusion

In addition to potential benefits brought by fruit production in cutover peatlands, blueberries can be used for ecological restoration. Once the different restoration steps are completed, blueberries can be planted by choosing the driest areas to avoid root asphyxiation. They contribute in stabilizing the substrate while benefiting from hay mulch. In addition, they favour the return of fauna by providing food.

6.5. References

6.5.1. Useful resources

6.5.1.1. Key informants in Canada

Quebec

André Gagnon, Agr.
Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec
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New Brunswick Wild blueberry Growers Association
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Email: Davidy@maine.edu
Web site: http://wildblueberries.maine.edu/index.html

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Sections on berries available on the MAPAQ Web site: http://www.mapaq.gouv.qc.ca/Fr/Productions/md/recherche/petitfruit/

The Wild blueberry Network Information Centre: http://nsac.ca/wildblue/

The Wild blueberry Producers Association of Nova Scotia: http://www.nswildblueberries.com/

Wild blueberry Association of North America: http://www.wildblueberries.com/

Wild blueberry Commission – University of Maine: http://wildblueberries.maine.edu/factsheets.html

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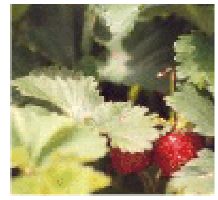

Gaylussacia baccata. Photo:
http://www.mlra.org/wildflowers/index.htm

Chapter 7:

Other berries

by

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Photo: Kenneth J. Sytsma, taken from
http://www.botany.wisc.edu/herbarium/

Photo taken from:
http://www.biopix.eu/

7.1. Introduction

Other species of berries sometimes marginalized or unknown will be presented in this chapter. Although few or no cultivation trials have been conducted in North American cutover peatlands, we believe that these species have a good potential on this type of site, either because they naturally grow in acidic or poor habitats, or because they showed promising results during experiments conducted in European cutover peatlands. In addition to showing interesting potential for fruit production, most of these species can be integrated in reclamation plans for peatlands and can help stabilize the substrate in cutover peatlands.

7.2. The lingonberry

Vaccinium vitis-idaea L. (also named the lingonberry, cowberry, partridgeberry or mountain cranberry; and *Airelle vigne d'Ida* in French) is a ground-covering shrub from the Ericaceae family, whose foliage lasts during winter. This plant is mainly found in well-drained soils, on rocky surfaces or in sandy acidic soils, notably near mouths of rivers in the Côte-Nord region. In Fennoscandia, lingonberry abundantly covers the grounds of Norway pine forests and can also be found in peat soils, although it is less frequent (Hjalmarsson and Ortiz 2001). Lingonberry produces red berries, ressembling cranberries, (Figure 7.1) which have antioxidant properties (Kähkönen *et al.* 1999), and can be consumed fresh or transformed into other products (juices, sauces, jams, etc.). Berries and leaves are also used for medicinal purposes (AAC 2003).

A

B

Figure 7.1: A) *Vaccinium vitis-idaea* L. Picture taken from: Britton and Brown (1913), in the USDA-NRCS PLANTS Database (2007). B) *Vaccinium vitis-idaea* fruits. Photo taken from http://www.saxifraga.de/foto_bot/vaccinium_vitisidaea.jpg.

Lingonberry is adapted to cool climates. It is harvested in the wild in all northern regions where it can be found.

Trials for lingonberry cultivation were mainly conducted in Europe. In Fennoscandia, it has been cultivated for over forty years; the majority of plantations are in sandy soils, which are more favourable for species growth. In an experiment comparing growing substrates, better fruit yields were achieved in sandy soils in the three years following planting, notably by adding fertilizer (optimal below 50 kg/ha; Hjalmarsson and Ortiz 2001). However, trials conducted in peat soils revealed that vegetative growth was much more significant than in sandy soils, which could result in higher fruit production in following years (Hjalmarsson and Ortiz 2001). Unfortunately, this has not yet been verified.

In North America, interest for this type of cultivation began towards the beginning of the 1990's (Finn 1999). St-Pierre (1996) published information on cultural practices. The Atlantic Cool Climate Crop Research Center (Agriculture and Agri-Food Canada) is also studying this species, and over 200 clones coming from wild plant populations were collected (AAC 2003).

In the 1980's, promising lingonberry cultivation trials in cutover peatlands were conducted in Estonia (Valk 1986). In Finland, trials were conducted by planting seeds directly into residual peat (S. Boudreau, pers. comm.) but no results are available. It's important to note that the North American species is a dwarf compared to its European counterpart (Marie-Victorin 1995). In New Brunswick, lingonberry has already been tested in cutover peatlands (with liming and fertilization) by the Department Agriculture and Aquaculture. Although seedlings survived the first winter, this trial was a failure, possibly due to inadequate drainage (G. Chiasson, 2002, New Brunswick Department of Agriculture and Aquaculture).

It is also possible to increase fruit yield in natural peatlands when this species is abundant; notably forest drainage can double lingonberry production (Kardell 1986). However, it's possible that yield of such practice will decrease once tree cover increases.

Commercial production of lingonberry is still very limited in North America. We know very little about its production costs, but they are probably similar to those of highbush blueberry (AAC 2003).

7.3. The black crowberry

Black crowberry (*Empetrum nigrum* L.; *Camarine* in French) is a small shrub growing like a tight carpet. Its leaves, which resemble conifer needles, last during winter (Figure 7.2). It can be found in nutrient poor soils, most notably in peatlands (sufficiently dried peatlands and cutover sites), but also on cliffs, in tundra and in spruce forests. Distribution is generalized in sub-arctic regions (Marie-Victorin 1995).

Black crowberry flowers (male or female, or having both sexes) appear from May to June and produce small black fruits, which have a relatively constant production from year to year. Fruits, rich in vitamin C and antioxidants (Appendix 1; Kähkönen *et al.* 1999), can be consumed fresh, in juices, dehydrated, incorporated into recipes (baking increases their flavour) or can also be used for food colouring. They can be harvested in autumn; they are generally sweeter after a frost, and can even persist until spring.

A **B**

Figure 7.2: *Empetrum nigrum*. Photos: N. Sloth (A) and J.C. Schou (B), taken from http://www.biopix.eu/

Black crowberry cultivation from stems (with roots) taken from an abandoned site was recently tested in a cutover peatland located in the Acadian Peninsula in New Brunswick (Acadian Peat Moss (1979) Ltd),. Few individuals survived transplantation during this experiment, without regards to control seedlings or fertilized seedlings (15 g/m^2 of phosphate rock). Survival rates were only 5% after two growing seasons.

7.4. The black huckleberry

Black huckleberry (generally *Gaylussacia baccata* (Wang.) K. Koch.; *Gaylussacia* in French), whose fruits are often harvested without distinguishing them from blueberries because of their resemblance, is a shrub measuring from 30 cm to 1 m in height wich can be found naturally in peatlands (Marie-Victorin 1995; Figure 7.3). Its autumnal bright red foliage provides spectacular colours to certain peatlands located in Southern Quebec and Eastern New Brunswick.

A

B

Figure 7.3: *Gaylussacia baccata*. A) Picture taken from: Britton and Brown (1913), in the USDA-NRCS PLANTS Database (2007). B) Photo: Robert W. Freckmann, taken from http://www.botany.wisc.edu/wisflora/scripts/detail.asp?SpCode=GAYBAC.

Currently, this species is not produced commercially, but it certainly possesses interesting potential. In Montana, Stark and Baker (1992) after studying its ecology, propose certain cultural practices. However, there is much confusion surrounding the huckleberry name because some authors mistake it for a wild blueberries species (*Vaccinium* spp.; Finn 1999).

Black huckleberry has not been tested in cutover peatlands. However, reproduction trials have been conducted by *Tourbières Lambert* in Rivière-Ouelle in collaboration with the Peatland Ecology Research Group in order to eventually conduct field trials.

7.5. Strawberries

Strawberry (*Fragaria* sp., *fraise* in French; Figure 7.4) is cultivated almost everywhere in Quebec in loams, sandy loams or in sands where pH level is between 6.0 and 6.5 (CPVQ 1997). It is to be noted that strawberry production requires intense cultural practices because it's an agricultural plant and not an introduced wild plant. Finnish researchers report good yields from strawberry cultivation in cutover peatlands following appropriate fertilizing and liming (Kukkonen *et al.* 1999, Vestberg *et al.* 1999).

A **B**

Figure 7.4: Flowers (A) and fruits (B) of wild strawberry plant. Photos: A) Réjean Martel, taken from http://www.naturecanada.ca/cwn_naturewatch_pw_species_strawberry.asp and B) Sukro, taken from http://www.canstockphoto.com/search.php?term=wild.

7.6. The blackberries

Rampant blackberry producing fruits (*Rubus hispidus* L., or brambles; *ronces* in French) have been observed in cutover peatlands of Southern Quebec, which leads us to believe that this species could be cultivated on this type of site. It would also be interesting to test the cultivation of different types of blackberries and raspberries in cutover peatlands.

Figure 7.5: *Rubus hispidus* in fruits. Photo: Kenneth J. Sytsma, taken from http://www.botany.wisc.edu/wisflora/

7.7. Conclusion

Many berries could present good cultivation potential in cutover peatlands, notably species from the Ericaceae or Rosaceae families, including fruits presented in this chapter. Foremost, it's preferable that the chosen species for cultivation is a peatland species or one that can support conditions found in cutover peatlands. If necessary modifications for the implementation of a more intensive culture aren't a problem for the potential site (for example, liming, intense fertilization or drainage modification) than, more demanding species, such as the strawberry, could be introduced.

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APPENDIX 1

Table showing total levels of phenols, anthocyanins, vitamin C and ellagitannins and antioxidant properties of cloudberry (from the yellow and red fruits genotypes) and of other berries mentioned.

Fruits	Phenols	Anthocyanins	Vitamin C	Ellagitannins	Antioxidant properties	Reference
	mg/ 100 g FM				µmol/g FM	
Rubus chamaemorus	231	103	61	252	24	Mylnikov *et al*. (2005)
Rubus chamaemorus	40					Mattila *et al.* (2006)
Black chokeberry						
Aronia ssp.	96					Mattila *et al.* (2006)
Aronia melanocarpa	2 556	428				Zheng and Wang (2003)
Aronia ssp.		1 480				Wu *et al.*(2004)
Serviceberry						
Amelanchier alnifolia		86-125				Ozga *et al.* (2006)
Amelanchier alnifolia		70-179				Ozga *et al.* (2006)
Amelanchier alnifolia	59					Mattila *et al.* (2006)
Elderberry						
Sambucus nigra		1 374				Wu *et al.*(2004)
Cranberry						
Vaccinium macrocarpon		34				C. Imbeault, Tourbière Lambert inc., pers. comm.
Vaccinium macrocarpon		25-65				Wang and Stretch (2001)
Vaccinium macrocarpon (cv. Ben Lear)	315	32				Zheng and Wang (2003)
Vaccinium oxycoccos	12					Mattila *et al.* (2006)

Fruits	Phenols	Anthocyanins	Vitamin C	Ellagitannins	Antioxidant properties	Reference
	mg/ 100 g FM				µmol/g FM	
Blueberry						
Vaccinium corymbosum (different cultivars)	181-390	93-235	5-14			Prior *et al.* (1998)
Vaccinium corymbosum (different cultivars)	233-473	63-157	5-9			Prior *et al.* (1998)
Vaccinium corymbosum (different cultivars)		83-250				Kalt *et al.* (1999)
Vaccinium corymbosum (cv. Serra)	412	120				Zheng and Wang (2003)
Vaccinium angustifolium	299	95	16			Prior *et al.* (1998)
Vaccinium angustifolium	295-495	91-191	3,6-9,7			Prior *et al.* (1998)
Vaccinium angustifolium		95-255				Kalt *et al.* (1999)
Vaccinium ssp.		25-495				Mazza and Miniati (1993) in Ozga *et al.* (2006)
Vaccinium ssp.	85					Mattila *et al.* (2006)
Crowberry						
Empetrum nigrum	33					Mattila *et al.* (2006)
Lingonberry						
Vaccinium vitis-idaea	652	45				Zheng and Wang (2003)
Vaccinium.vitis-idaea	24					Mattila *et al.* (2006)

FM : Fresh mass

From:

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APPENDIX 2

Planting monitoring

For each culture, adequate monitoring is an essential tool to efficiently manage plantations. An orderly system of data collection will allow for the surveillance of plantation performance, problems which may occur and efficiency of various management operations.

Here is the information which should be catalogued and preserved:

- A plantation plan (orientation of rows, spacing between and in rows, windbreaker position, etc.);
- Species and cultivars used as well as their origin and the type of plants (cuttings, suckers, transplants, caliber, etc.);
- The number of seedlings planted and planting dates;
- The average height of seedlings when planted;
- The fertilization plan: type of fertilizer, quantity, application method and dates as well as results from initial soil analysis, results from foliar tissue analysis and observed symptoms of deficiency;
- All information regarding other management operations: irrigation (dates, quantity), cutting (dates, estimation of the amount of cut branches), renewal of dead plants (planting dates, species or cultivars, origin, type, number);
- Monitoring of plant development: dates of bud breaking, dates of flowering, dates of fruit maturation;
- Monitoring of weeds (observation dates, estimate of the extent and degree of competition, control methods used and application dates);
- Monitoring of diseases and pests (observation dates, symptoms, estimate of extent and degree of infestation, methods of eradication used);
- Annual measurement of plant performance:
    - <u>Survival</u>: measured over entire plantation. This measure helps evaluate the number of plants to replace;
    - <u>Height</u>: measured randomly using samples from the plantation, for example, 10 samples from 10 plants. This measure helps to calculate annual growth (height during the present year – height during the previous year);
    - <u>Crown diameter (optional)</u>: measured randomly using samples from the plantation, for example, 10 samples from 10 seedlings. Two widths are measured for each plant, one is the widest (D1) and one perpendicular to the first (D2). These two measures help calculate the average diameter of the crown [(D1 x D2) / 2];

- <u>Fruit yield</u>: measured randomly using samples from the plantation, for example, 10 samples from 10 seedlings. For each sample, fruit is harvested and weighted, and yield per seedling or per hectare can be calculated;
- <u>Average fruit size</u> (optional): measured using random samples from fruit harvest, for example, for twenty fruits. This measurement can also be estimated by the number of fruits found in a cup