Conditions favouring survival of cloudberry (*Rubus chamaemorus*) rhizomes planted in cutover peatland

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SUMMARY

Four experiments aimed to assess the success of cloudberry establishment and its productivity in abandoned cutover peatland. Two experiments tested the length of the rhizomes (15, 20 and 25 cm) and the depth of planting (5 and 10 cm). One of these showed that the rhizomes should be at least 20 cm long and be planted at a depth of 5 cm to obtain better survival, whereas the other was inconclusive. The advantage of autumn over spring planting for the survival of cloudberry rhizomes was highlighted.

KEY WORDS: vegetative growth, propagation, abandoned peatland.

INTRODUCTION

The extraction of peat for horticultural purposes leaves very large surfaces of cutover ombrotrophic peatland, which can be restored (Rochefort *et al.* 2003) or reclaimed depending on the site conditions. Reclamation by planting with trees or edible berry plants could be considered as a stand-alone measure, or combined with ecological restoration when conditions are favourable. Abandoned sites are often characterised by a varying depth of peat left over the mineral sub-soil. Moreover, peat extraction affects peatland hydrology by causing compaction of *in-situ* peat, increased water table fluctuations, lower water retention *etc*. (Price 2003). Cutover peatlands are also subject to wind erosion (Campbell *et al*. 2002) and peat oxidation (Waddington & McNeil 2002), and the peat chemistry is closer to that of fens than to that of natural bogs (Wind-Mulder *et al*. 1996). For these reasons, not all plant species can be successfully introduced, and preparation such as blocking drainage ditches is sometimes necessary.

Several fruit species such as bog cranberry (*Vaccinium oxycoccos* L.), lowbush and highbush blueberry (*Vaccinium angustifolium* Ait. and *V. corymbosum* L.), black chokeberry (*Photinia melanocarpa* (Michx.) Robertson & Phipps), shadbush (*Amelanchier alnifolia* (Nutt.) Nutt. ex M. Roemer) and the common elderberry (*Sambucus canadensis* L.) have been tested for fruit production potential on cutover peatlands in Europe (Selin 1996, Noormets *et al.* 2004) and North America (Bussières *et al.* 2008). The species selected for this study is the cloudberry (*Rubus chamaemorus* L.), which has been tested in northern Europe (Rapp 2004). In this article we describe experiments to identify growing techniques suitable for northern North America, where the species grows well on undamaged bogs.

METHODS

Experimental sites

New Brunswick site

Two experiments were conducted on Lamèque Island (47º48'47"N, 64º37'24"W) in north-east New Brunswick. This region is characterised by a maritime climate. According to 1993–2007 meteorological data (Bas-Caraquet New Brunswick meteorological station, 47°48'00"N, 64°49'48"W; Environment Canada 2008), the monthly average temperatures were 9, 16, 19 and 19 °C respectively for the months of May to August and the rainfall averaged 83, 62, 74, and 67 mm for the same months. Mean annual temperature was 5.4° C and mean annual precipitation was 1067 mm, of which 749 mm fell as rain.

The cutover site where the experiments were conducted is managed by Acadian Peat Moss (1979) Ltd. and was abandoned in 2001. It is well drained by ditches installed previously for peat extraction; the water table was more than 80 cm below the ground surface throughout the summer and autumn. The cloudberry rhizomes were collected from the edges of drainage ditches in the same peatland, cut to the size needed (15 or 25 cm), and transplanted into residual H4 peat (von Post scale) on the experimental plots only a few hours after collection unless otherwise stated. No other fieldwork or pre-treatment was carried out before planting.

Québec site

Two further experiments began in 2004 on cutover peatland at Pointe-Lebel (49°10'00"N, 68°12'00"W) in the province of Québec, eastern Canada. This region is characterised by a coastal climate. Temperature and precipitation during the three annual growing seasons of the study were similar to the average climatic conditions of the last 30 years (Baie-Comeau weather station, 49°07'48"N and 68°12'00"W; Environment Canada 2008) except that August was wetter than average in 2004 and 2005. Monthly average temperatures were 7, 13, 16 and 15 °C respectively for the months of May to August and monthly average rainfall was 85, 84, 89, and 82 mm in the same months. The mean annual temperature was 1.5 °C and mean annual precipitation 1015 mm, of which 684 mm fell as rain.

This site is managed by Premier Horticulture Ltd., was abandoned more than ten years ago, and had been untreated since. The experimental plots were set up between two drainage ditches (installed previously for peat extraction) which were blocked at their lower extremities in order to maintain the water table level at approximately 50 cm below the ground surface. In the spring and autumn of the first year (2005), the water table was at approximately -50 cm, whereas it ranged between -45 and -130 cm during the summer. The average humification of the residual peat was H4 (von Post scale). Before the experiments began, the uppermost 5 cm of peat was harrowed and fluffed up (Théroux Rancourt *et al.* 2009). The rhizomes used for these experiments were collected from the edges of drainage ditches in an adjacent site. They were collected on 25 October 2004 for the rhizome length and planting depth trials, and in autumn 2004 (25 October) or spring 2005 (24 May) for the planting season trials. The rhizomes were cut to size (15, 20 or 25 cm) and stored at 4 °C until transplanting, which was done approximately 24 hours after harvest.

Rhizome length and planting depth trials

According to the Norwegian cloudberry growers' guide (Rapp 2004), the rhizome sections selected for planting should be 10–15 cm in length. The length of the planted rhizomes is important because it influences fruit productivity (Jean & Lapointe 2001). Longer rhizomes might thus enhance the success of emerging shoots. The planting depth can also affect survival *via* depletion of reserves, and a decrease in shoot vigour has been observed with deeper planting of another clonal species, *Rumex alpinus* (Klimes *et al.* 1993). Rapp (2004) recommends planting depths of 5–10 cm for bare rhizomes and 10 cm for rooted plantlets.

Experiment NB-l

This experiment, carried out in New Brunswick, aimed to test the effect of rhizome length on survival. Two rhizome lengths, 15 and 25 cm, were tested over two seasons using a completely randomised four-plot experimental design (n=2). One repetition was planted on 18 October 2005 and the other on 17 May 2006. Each plot (experimental unit) measured 3 m x 4.5 m and contained five rows 60 cm apart, each with 15 rhizomes spaced at 30 cm along the row. Rhizomes were planted 7 cm deep.

Percentage survival of rhizomes was estimated during two growing seasons (on 12 July 2006 and 19 June 2007), by counting the number of surviving plants and dividing by the total number initially planted in each plot.

Experiment Q-ld

In Québec, the effect on cloudberry establishment of rhizome length combined with planting depth was tested using rhizomes 15, 20 and 25 cm long, planted at 5 and 10 cm depth, in a completely randomised factorial design replicated four times (n=4). The rhizomes were planted on 27 October 2004 in experimental units measuring 2.25 m x 2.45 m, each containing six rows (45 cm apart) of five rhizomes spaced at 30 cm along each row. Thus, 24 plots were planted in total (3 length treatments x 2 depths x 4 replicates).

The variables measured in this experiment were: percentage survival (number of surviving plants divided by the total number of rhizomes initially planted in each plot), the number of leaves within each plot and the average individual leaf area. Plant survival and the number of leaves per plot (converted to leaves m^{-2}) were measured on 28 July 2005 and 21 July 2006 (respectively 8 and 20 months after transplanting). Percentage survival was also estimated on 10 July 2007 (28 months after transplanting). Leaf area (*LA*) was calculated for each leaf in the plot from leaf diagonal measurements (from an inferior lobe to the opposite superior lobe) made in 2005 and 2006 (early August) using the following equation:

$$LA = 0.5242 \times e^{(0.7158 \times \text{diagonal})} \quad (r^2 = 0.96, P < 0.001).$$

It should be noted that this formula is valid only for leaves with diagonal less than 4 cm, which was the case in the plots studied here.

Experimental design for planting season trials

The time (season) of planting is another factor that might affect rhizome survival and initial plant growth. Clonal plant species usually exhibit a cyclical pattern of growth in spring and storage of reserves in autumn (Gallagher *et al.* 1984, Zasada *et al.* 1994). Planting cloudberry rhizomes in early autumn could be beneficial because their sugar concentration is high in September and early October, and then falls from October to December (Kaurin *et al.* 1981). Thus, rhizomes transplanted in early autumn have the reserves needed to survive the winter and produce shoots the following spring. Rhizomes harvested in spring have lower energy reserves, having used them for maintenance during the winter; lower survival may then be expected.

Experiment NB-s

The effect of planting season was tested in New Brunswick by comparing the survival of rhizomes planted to a completely randomised design on 13 November 2003 and 11 May 2004. The rhizomes for spring planting were collected the previous autumn and kept under the snow all winter. After the snow melted, they were stored in a refrigerator (4°C) until planting, and they were not dormant at planting time. Rhizomes 15 cm in length were planted at a depth of 10 cm. Four experimental plots of 90 rhizomes were set up for each planting season, each consisting of six rows (60 cm spacing) of 15 rhizomes spaced at 30 cm along the row. The percentage survival was estimated on 10 August 2004, i.e. at the end of the first growing season.

Experiment Q-s

The effect of planting season on the survival and growth of cloudberry was also tested at the Québec site by comparing rhizomes planted under similar conditions on 27 October 2004 (autumn) and 26 May 2005 (spring). For each treatment, the rhizomes were planted within 24 hours of harvesting. Six 2.25 m x 2.45 m plots were set up for each season in a completely randomised design, giving a total of 12 plots (2 planting seasons x 6 replicates). Each plot contained six rows (45 cm spacing), each with five 20-cm long cloudberry rhizomes spaced at 30 cm along the row and planted at a depth of 7 cm. The variables measured were the percentage survival (28 July 2005, 21 July 2006 and 10 July 2007), the number of leaves per plot (28 July 2005 and 21 July 2006) and individual leaf areas (August 2005 and August 2006).

Statistical analysis

All statistical tests were performed using *Statistix 8* software (Statistix 8, Version 8.0, Analytical Software). The effect of rhizome length (New Brunswick site) on rhizome survival was tested using an ANOVA for repeated measurements (years). The combined effect of planting depth and rhizome length on survival, the number of leaves and the individual leaf area was tested using ANOVAs with two classification criteria (length and depth) for repeated measurements (years). LSD multiple comparisons tests were also performed when the ANOVA indicated significant differences. For the experiments testing the effect of planting season on survival and, where applicable, the number of leaves and leaf area, *t*-tests were performed.

RESULTS

Effects of rhizome length and combined rhizome length and planting depth

Experiment NB-l

The survival of longer rhizomes was not statistically better ($F_{length1,2}$ = 2.86, P_{length} = 0.23) at the New Brunswick site, which had a relatively dry substrate all year round and slightly warmer (2–4°C monthly) and drier summers than the Québec site. For the first year of measurements, the survival was 34 ± 3% and 53 ± 12% for the 15 cm and 25 cm rhizomes respectively, whereas it was 25 ± 3% and 41 ± 8% for the second year (Figure 1). It should be noted that survival decreased by about 10% between the first and second years ($F_{year1,2}$ = 26.0, P_{year} = 0.04).

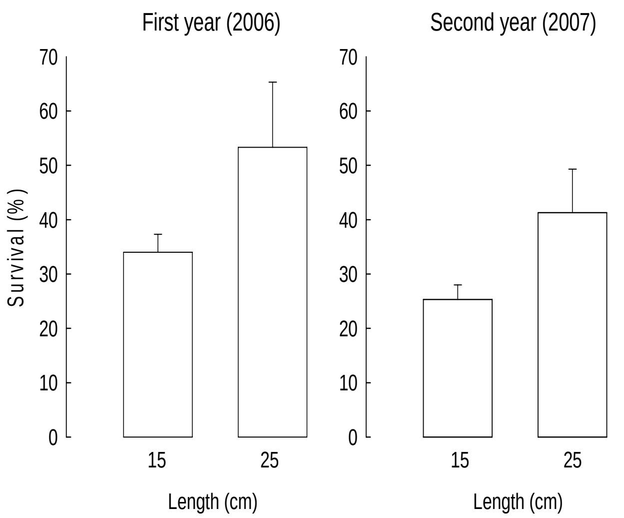

Figure 1. Experiment NB-l: survival (%) for the different cloudberry rhizome lengths (15 and 25 cm), one and two years after planting at the New Brunswick site (mean ± 1 SE; n = 2).

Experiment Q-ld

At the Québec site, which has cooler and more humid summers (and better peatland re-wetting conditions) than the New Brunswick site, survival was better for rhizomes planted at 5 cm than at 10 cm depth ($F_{1,36}$ = 7.65, P = 0.01; Figure 2). Furthermore, longer rhizomes (20 and 25 cm) had better survival ($F_{2,36}$ = 10.8, P = 0.0008) than shorter ones (15 cm). Both effects were still present in the third growing season. As at the drier cutover peatland site in New Brunswick, survival decreased significantly during the second and third years of the study ($F_{2,36}$ = 33.0, P < 0.0001). For the number of leaves per m^2, the significance of the triple interaction depth × length × year ($F_{2,18}$ = 6.37, P = 0.0081) is difficult to interpret. However, analysis of the individual effects of rhizome length and year suggested that the 20 cm and 25 cm rhizomes produced more leaves than the 15 cm ones ($F_{2,18}$ = 9.34, P = 0.002), with the first year of growth (2005) being the most productive ($F_{1,18}$ = 35.6, P < 0.0001). The largest leaf areas were for 20 cm and 25 cm rhizomes ($F_{2,18}$ = 6.54, P = 0.007) and for those planted at 5 cm depth ($F_{1,18}$ = 4.55, P = 0.05).

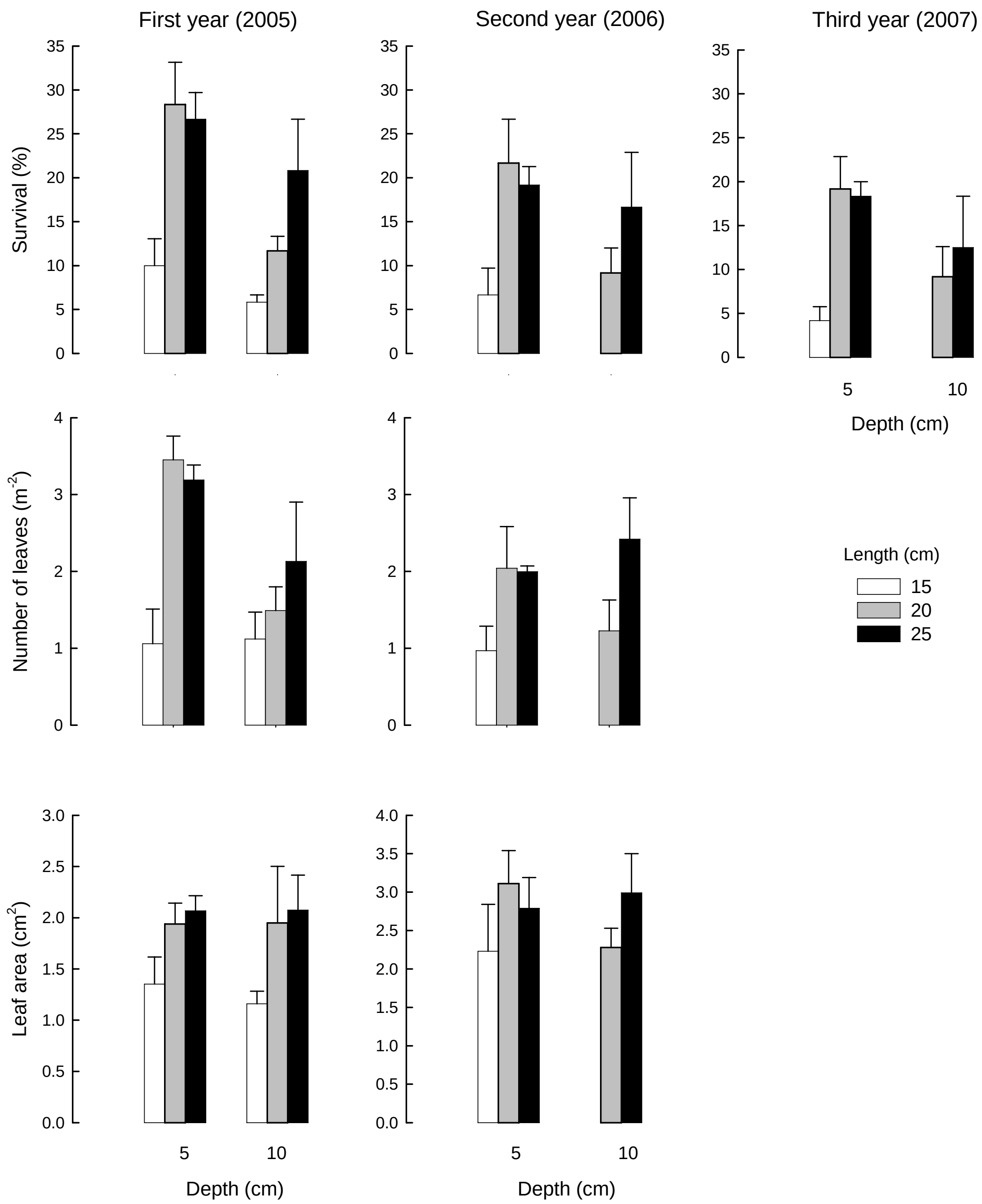

Figure 2. Experiment Q-ld: survival (%), number of leaves (m^{-2}) and individual leaf area (cm²) for the different combinations of planting depth (5 and 10 cm) and rhizome length (15, 20 and 25 cm) one, two and three years after planting cloudberry rhizomes at the Québec site (mean ± 1 SE; n = 4).

Effect of planting season

Experiment NB-s

In the well drained New Brunswick cutover peatland, the survival of rhizomes planted in autumn (69 ± 2%) was better than that of rhizomes planted in spring (43 ± 3%) (t = 7.4, P = 0.0007; Figure 3).

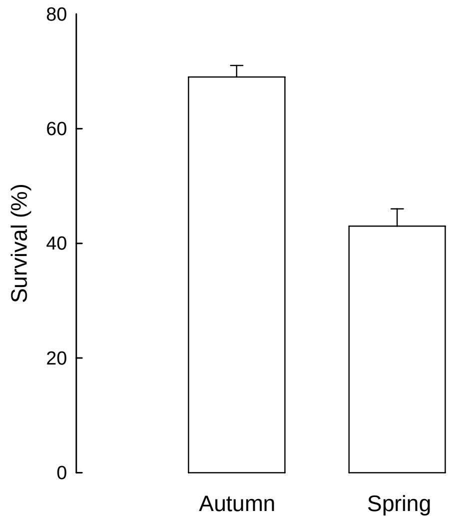

Figure 3. Experiment NB-s: survival (%) after one year for cloudberry rhizomes planted in autumn and in spring at the New Brunswick site (mean ± 1 SE; n = 4).

Experiment Q-s

At the Québec site, where the lower ends of the drainage ditches were blocked following peat extraction, survival was better in the plots where rhizomes were planted in autumn for the three studied growing seasons (1st: t_{10} = 2.37, P = 0.04; 2nd: t_{10} = 2.42, P = 0.04 and 3rd: t_{10} = 2.21, P = 0.05; Figure 4). For the two years in which the number of leaves was assessed, the autumn planting produced more leaves than the spring planting (t_{10} = 2.40, P = 0.05 and $t_{6,9}$ = 2.49, P = 0.03). The planting season had no effect on the individual leaf area during the first and second years (t_{10} = -1.11, P = 0.3 and $t_{5,7}$ = 1.73, P = 0.14).

DISCUSSION

Effects of rhizome length and combined rhizome length and planting depth

From the combined rhizome length and planting depth trials, we can state that the optimum rhizome length at planting is at least 20 cm. Survival was better for rhizomes planted at 5 cm than at 10 cm depth. The lack of significant differences at the New Brunswick site could be explained by the limited number of replicates (type II error); nevertheless Figure 1 shows the same tendency as that observed at the Québec site, i.e. better survival for longer rhizomes. Similar results have been reported with sectioned rhizomes of other species (*Agrostis castellana*, *Agropyron repens*, *Elymus farctus*, *Mentha arvensis*), 4 cm being the minimum length for these species and 7.5 cm the deepest planting depth that ensures survival (Håkansson 1971, Harris & Davy 1986, Ivany 1997, Batson 1998). The inability of the rhizomes to produce shoots when they are very fragmented and planted at greater depths may be explained by the exhaustion of energy reserves. Physiological integration is broken in cut rhizomes, and isolated ramets must survive adverse conditions with much smaller stored reserves than intact clones (Marshall 1990). In a study of *Solidago altissima,* Cain (1990) also suggested that ramet size was directly related to the size of the supporting rhizome. The vigour of the shoot also tended to decrease with planting depth in another clonal species, namely *Rumex alpinus* (Klimes *et al.* 1993). The *R. alpinus* rhizomes possessed sufficient carbohydrate reserves to survive without photosynthesis, but the complete lack of starch grains at the apices of more deeply planted rhizomes indicated that exhaustion of reserves was imminent. In cloudberry, carbohydrates account for only 23% of the rhizome dry biomass, indicating a much lower storage capacity than that observed in some spring flowering plants (Lapointe & Molard 1997, Lapointe 1998). It is possible that this physiological constraint contributed to the lower survival observed in the 15 cm rhizome trials.

Another hypothesis to explain the low survival and low initial number of leaves for the more deeply planted rhizomes is the impact of the anoxic conditions that are typically present in the lower part of the soil profile. In a study of tree planting on peatland, Aro & Kaunisto (2003) reported that tree roots were concentrated within the uppermost 10–14 cm of cutover peatland. The water table is generally low in cutover peatlands (Price 1997, 2003), but can be high early in the season and remains high under rainy conditions in spring. At the site with blocked drainage ditches (Québec site), the water table rose to 10 cm below the ground surface in spring (data not presented). Because moss peat from an adjacent site had been spread with machinery over this site, the top few centimetres were relatively aerated. On the other hand, the peat soil below 5 cm depth had been compacted by machinery during site preparation, and this could

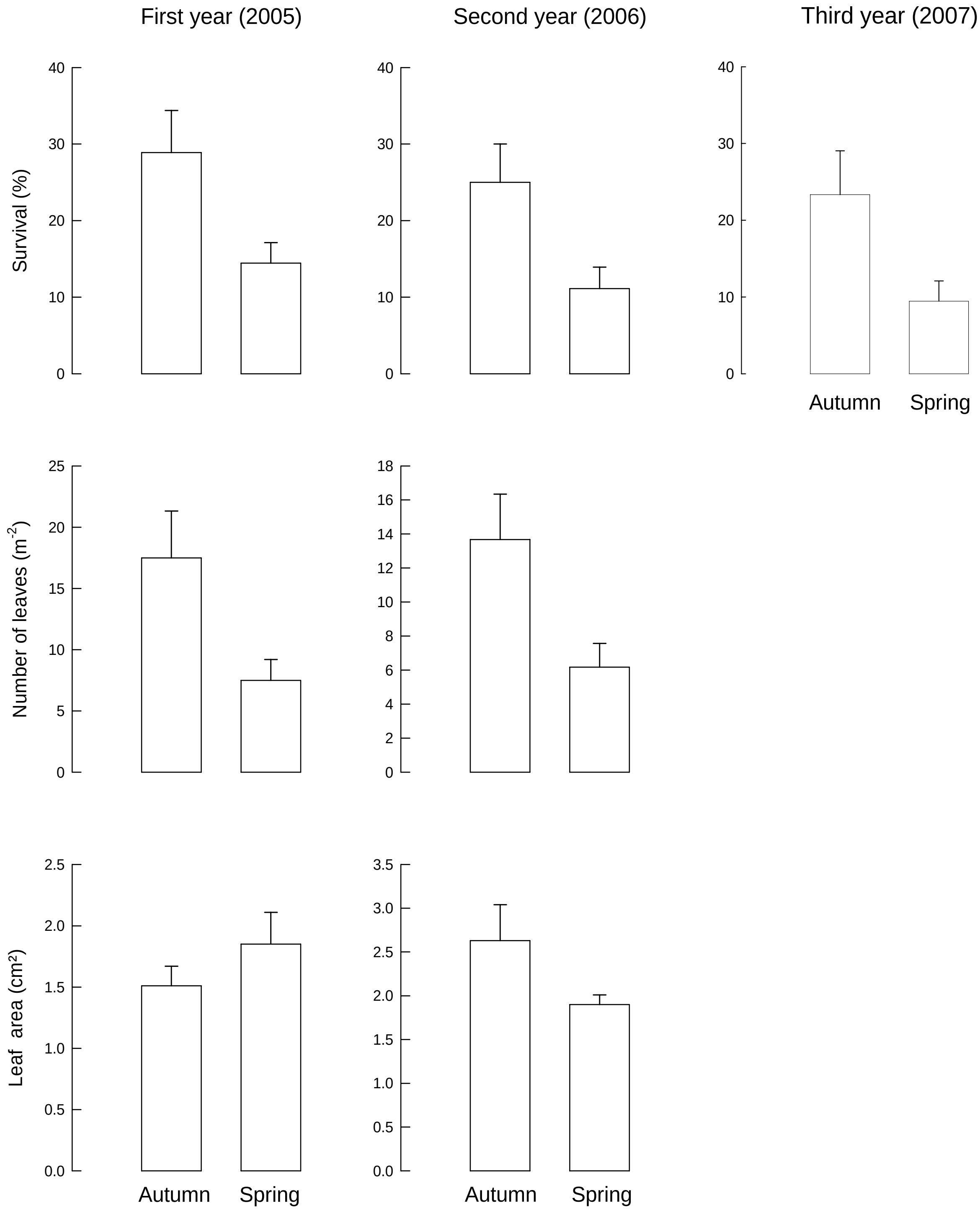

Figure 4. Experiment Q-s: survival (%), number of leaves (m^{-2}) and individual leaf area (cm^2) for cloudberry rhizomes planted in the autumn or in the spring one, two and three years after planting at the Québec site (mean ± 1 SE; n = 6).

also partly explain the lower survival of rhizomes planted at 10 cm depth. Survival of cloudberry in an experiment conducted on freshly tilled peatland in New Brunswick was over 75%, which is higher than on more compacted fields (G. Chiasson, New Brunswick data not presented). Finally, the frost heaving observed at the Québec site plots early in the spring of the second year may have reduced the survival of some of the more shallowly planted rhizomes. However, the lack of energy remains the most plausible explanation for the effect of planting depth on the survival and sizes of emerged plants.

Effect of planting season

According to Rapp (2004), there should be no difference in emergence between cloudberry rhizomes planted in spring and autumn. It is demonstrated here that autumn planting is beneficial in terms of survival and the number of developed leaves under two different sets of climatic and site conditions. The effect does not fade with time; the plots planted in autumn continued to have higher leaf density even though survival and the number of leaves generally declined over the years. Rhizomes should be transplanted no later than mid-October to maximise reserve content and thus survival (Kaurin *et al.* 1981). However, when still-dormant rhizomes are planted in the spring, survival is similar to that observed with autumn planting (G. Chiasson, unpublished data).

In a sedge wetland restoration experiment in Minnesota, USA (44°48'N, 93°35'W), spring appeared to be the best season for planting some perennial species (Yetka & Galatowitsch 1999). Approximately 10 cm sections of the youngest parts (apices) of the rhizomes were collected in mid-September or in mid-May and re-planted two days later. For *Carex lacustris*, survival was better with spring planting. Lack of reserves in the underground tissues in spring for individuals planted the previous autumn, and the absence of emerged shoots to allow oxygen transport to the dormant rhizome, may have reduced survival of the transplants (Wijte & Gallagher 1991, Yetka & Galatowitsch 1999). This does not seem to be the case for autumn-planted cloudberry rhizomes, however. Earlier growth of autumn-planted than spring-planted rhizomes may have led to more effective avoidance of anoxia in the first spring. Spring-collected rhizomes whose dormancy was already broken may have suffered significant stress during transplanting, decreasing their survival. Furthermore, a practical argument for autumn planting is the greater availability of manpower at that time of the year for cloudberry production led by the peat industry.

To increase the survival of cloudberry on cutover peatlands, other variables that should be taken into account include the health and age of rhizomes, the origin of rhizomes including the possible use of selected cultivars, soil physical properties, timing of rhizome harvesting and mineral fertilisation. However, the ongoing effects of the different treatments over two and even three years underline the importance of identifying the optimal planting conditions. The survival of transplanted cloudberry rhizomes is still too low to make large-scale production commercially feasible, but the knowledge gained during this study points the way for future research on this interesting berry.

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