Rhizome sectioning and fertilization increase the productivity of cloudberry in natural peatlands

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Bellemare, M., Rochefort, L. and Lapointe, L. 2009. **Rhizome sectioning and fertilization increase the productivity of cloudberry in natural peatlands**. Can. J. Plant Sci. **89**: 521–526. The effects of combining rhizome sectioning and in-depth mineral fertilization on cloudberry (*Rubus chamaemorus* L.) growth and production in a natural peat bog were determined over four growing seasons. Observed enhancements of growth and fruit production included: increases in the density of ramets and leaves from the second year; increased flower density from the third year; and increased fruit density from the fourth year. No effect on fruit size was observed. These results demonstrate that it is possible to stimulate growth and productivity of cloudberry by cultural treatments applied to natural mires.

Key words: Wild berry, *Rubus chamaemorus*, fruit yield, rhizome sectioning, mineral fertilization, cloudberry

Bellemare, M., Rochefort, L. et Lapointe, L. 2009. **Rhizome sectioning and fertilization increase the productivity of cloudberry in natural peatlands**. Can. J. Plant Sci. **89**: 521–526. Les effets combinés du sectionnement des rhizomes et d'une fertilisation minérale en profondeur sur la croissance et la production de la chicouté (*Rubus chamaemorus* L.) ont été évalués en tourbière naturelle sur une période de 4 ans. La densité des ramets et des feuilles a augmenté à compter de la deuxième année, la densité de fleurs à partir de la troisième année, et le rendement en fruits seulement la quatrième année suivant l'application du traitement combiné de sectionnement et de fertilisation. Aucun effet sur la taille des fruits n'a été observé. Ces résultats montrent qu'il est possible d'augmenter la croissance et la productivité de la chicouté en milieu naturel.

Mots clés: Petits fruits, *Rubus chamaemorus*, sectionnement des rhizomes, fertilisation minérale, rendement en fruit, croissance végétative, chicouté

Cloudberry, *Rubus chamaemorus* L., a perennial species common in ombrotrophic peatlands of the Northern hemisphere (Resvoll 1929), produces an edible fruit of commercial value (Nilsen 2005). However, one of the biggest issues constraining the development of a cloudberry market is the fact that in natural peatlands, fruit yields are rather low and highly variable from year to year (Resvoll 1929; Ågren 1988). Finding ways to improve cloudberry yields in natural peatlands was the main focus of this study.

Cloudberry propagates mainly vegetatively through rhizomes (Nilsen 2005). Each shoot or ramet that develops from the rhizome apex carries one to three leaves, a single flower and – in the case of female flowers – a single fruit composed of 1 to 14 drupelets (Jean and Lapointe 2001). Ramet density is low along the rhizome. Rhizome sectioning is a means to propagate perennial plants, but results are highly species-dependant. For example, rhizome sectioning for *Schoenoplectus* spp. was found to initially increase ramet production whereas for *Cladium mariscoides* Muhl. Torr., it favoured an aggregation of ramets (Pauliukonis and Gough 2004). *Leymus chinensis* (Trin.), a perennial clonal species did not respond to rhizome sectioning (Wang et al. 2004). Suppression of aerial biomass by mowing or burning can also stimulate bud emergence on rhizomes or stolons and increase fruit production. This is the case for blueberries and cranberries (Strik and Poole 1992; Penney et al. 1997). As dormant buds are located on the rhizomes rather than on the aerial shoots in cloudberry, rhizome sectioning might be more appropriate than shoot pruning to stimulate fruit production.

Rhizome sectioning combined with fertilization might improve cloudberry productivity in natural habitats, even though soil fertility was apparently not indicated as important in controlling its natural plant density (Rapp 2004). Shoot growth in cloudberry was found to be limited by nitrogen, whereas other nutrients limited roots and rhizomes (Saebø 1970). Phosphorus content is generally high in cloudberry (Saebø 1968), but the very low concentrations in peatlands suggest that phosphorus fertilization could improve fruit development (Saebø 1977). Fertilization assays with cloudberry have produced inconclusive results (Østgård 1964; Mäkinen and Oikarinen 1974; Kortesharju and Rantala 1980), but these may have stemmed from the method of nutrient application, which was mainly surface fertilization. Apparently, below-ground fertilization would be more

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beneficial to cloudberry than surface fertilization, which mostly benefits the other species (Rapp and Steenberg 1977). The objective of this study was to determine if a combination of rhizome sectioning and in-depth fertilization can improve cloudberry productivity in a natural peatland.

MATERIALS AND METHODS

Experimental Site

The experimental site is part of a 2600-ha ombrotrophic peatland in the North Shore region (49°10′N–68°12′W) of Quebec, Canada. Rhizome sectioning and fertilization treatments were applied in 2004, and plant response was monitored over the following four growing seasons (2004 to 2007). In the selected plots, *Sphagnum rubellum* was the dominant species of the moss layer, but *Sphagnum fuscum*, *Sphagnum magellanicum*, *Polytricum strictum* and lichens of the *Cladonia* spp. genus were also found in smaller proportions. The herbaceous stratum included *Empetrum nigrum* in many locations, but was dominated by cloudberry with an average percent cover of ca. 20%. *Chamaedaphne calyculata* and other ericaceous shrubs and small *Picea mariana* composed the shrub stratum.

At the site, historical mean monthly temperatures are, respectively, from May to August, 6.6, 12.6, 15.6 and 14.5°C, based on measurements from 1971 to 2000 (Environment Canada 2006). The mean annual temperature is 1.5°C. Historical mean monthly precipitation is, respectively, 85, 84, 89 and 82 mm. Historical mean annual precipitation is 1015 mm of which 684 mm falls as rain. Meteorological data measured during the 4 yr of the study were similar to the 30-yr climatic norms, except there was higher than normal rainfall in June in 2007 and in August of 2004, 2005 and 2007, and lower than normal rainfall in May 2007.

Experimental Design

We established an experiment in a natural stand of cloudberry. The experimental design was a completely randomized block with six blocks. In each block, a combination of rhizome sectioning and fertilization was randomly assigned to one of two 3-m × 3-m plots, and the other plot was left untreated as the control. The two plots were located 2 m from each other and each block was separated by at least 2 m. Rhizome sectioning was done using a chainsaw equipped with a 50 cm blade. Cuts were made downward, 1 m apart and across the plots including along the four edges, to a depth of 30 cm in the peat soil. The sectioning was done before shoot emergence in early spring.

After fruiting, 45 g of fertilizer was inserted into each of sixteen 10-cm-deep holes per plot, which were laid out in a 1-m × 1-m grid pattern, as recommended by Rapp (2004). The fertilizer was composed of 11% N (6.5% as NH_4 and 4.5% as NO_3), 5% P, 17.6% K, 2.3% Mg, 2.3% Ca (as $CaCl_2$), 9.5% S, 0.03% B, 0.3% Mn, 0.03% Zn and 0.002% Mo. This formulation was adapted from the trials done at the Holt Norwegian Research Center, Tromsø (Inger Martinussen, Bioforsk Holt, Norway, personal communication).

Plant Performance

We evaluated cloudberry productivity and fruit yield in four 1-m × 1-m quadrats per plot, located 30 cm from the edges of the plot and 40 cm from each other. We counted the number of cloudberry ramets and leaves biweekly every year in all experimental units. In mid-July, leaf diagonals were measured to calculate the leaf area. To establish the relation between leaf diagonal length (DL) and leaf area, 100 cloudberry leaves, with a diameter of 2 to 8 cm, were harvested in the peatland in July 2004. For each leaf, DL was measured with a ruler and area was measured using an area meter (LI-COR 3100 area meter, LI-COR Biosciences, Lincoln, NE). The following relationship was established:area $= -2.288 + (1.226 \times \mathrm{DL}) + (0.4283 \times \mathrm{DL}^2)$.

The r^2 for the equation was 0.96 and P was <0.001. This relationship holds only for leaves 2–8 cm in diameter, which was the case for all leaves measured in this study. In the second, third and fourth growing seasons, we monitored phenology and development every 3 d from flower bud emergence to the end of flowering, and then weekly up to fruit maturity. More precisely, we determined bud sex, counted the flowers and tagged the counted male and female flowers with plastic tie-wraps of different colors. During the second year, the total number of male flowers produced within each plot was counted for the whole season. This approach to determining flower populations was time consuming, especially for male flowers that were more abundant than female flowers. In the third and forth years, we determined instead the maximum number of male flowers that were opened in a given day based on at least five daily visits during the peak of flowering. Female flowers continued to be tagged and counted over the whole season. Flower and bud abortion were also monitored. At the end of each season, we harvested the mature fruits, counted the drupelets, and measured fruit fresh mass and dry mass after dehydrating the fruit for 48h at 70°C.

Statistical Analyses

Statistical analyses were done using the GLM procedure of SAS software (v. 6.12, SAS Institute, Inc., Cary, NC). To determine the effects of rhizome sectioning combined with fertilization, we used two-way split-plot ANOVAs. The combined sectioning and fertilisation (treated vs. control) was the main factor, and growing years (1–4) was the secondary factor. Analysis of flower and fruit production were for data collected only in last 3 yr of the study and did not include data from one block because it did not produce any female flowers. If an interaction term was significant, the treatment effect was further investigated separately by year using the Slice option of

LSMEANS function. Some of the variables (number of leaves, leaf area and number of female and male flowers) were transformed ($\mathrm{Log}_{10}\ x+1$) prior to the analyses to reduce heteroscedasticity. The level of significance used in all analyses was $P \leq 0.05$.

As the male flower numbers were estimated with different techniques in the second compared with the third and fourth year, we analysed them separately with one-way ANOVAs. In this case, we used the Statistix 8 software (Statistix 8, Version 8.0, analytical software).

RESULTS AND DISCUSSION

Vegetative Growth

Ramet and leaf densities were higher in response to sectioning and fertilization (Fig. 1). The effect appeared in the second year and became more apparent in the third and fourth growing seasons. In Norway, a ploughing treatment was found to stimulate aerial stem production in cloudberry (Østgård 1964). Under natural conditions, ramet population densities of 15 per m^2 in a black spruce forest, 19 per m^2 in a *Sphagnum*-dominated bog and 62 per m^2 in a forested bog have been found (Korpelainen et al. 1999), whereas a mean of 88 per m^2 was found at the end of the study in control plots. However, Flower-Ellis (1980) observed an average leaf density of 325 ± 30 leaves m^{-2} in a permafrost peatland site, which is higher than the highest density found during the present study, which was slightly less than 300 leaves m^{-2}. We also found an increase with years in individual leaf area (Fig. 1). However, the leaf areas of ≤ 9 cm^2 we found were always less than those observed by Lohi (1974) in an open *Sphagnum* peatland (16 cm^2) and in a forested bog (28 cm^2), but similar to that observed by Flower-Ellis (1980) in a permafrost peatland (5.8 cm^2). Larger leaves in response to the treatment in the second year may have allowed cloudberry to accumulate more reserves in the rhizomes, which contributed to the increased ramet production in the third year.

The response to rhizome sectioning and fertilization was slow or delayed. In other species such as *Agropyron repens,* new shoots were visible 12 d after rhizome sectioning and fertilization (McIntyre 1972). Stimulation of vegetative growth by rhizome sectioning could be caused by a reduction of apical dominance and the induction of lateral bud growth [Maun (1984) in a study with *Ammophila brevigulata*]. Other factors that initiate lateral bud growth, as identified from studies with *Agropyron repens*, are shading of the parent plant; rhizome sectioning from the parent plant or in several small units; removal of the rhizome apex; and significant addition of nitrogen (Rogan and Smith 1976; McIntyre 2001). The responses of higher ramet density and leaf area can also be explained solely from improved mineral nutrition as shown in other studies of cloudberry (Østgård 1964; Taylor 1971; Kortesharju and Rantala 1980). Noteworthy is that in the present study the

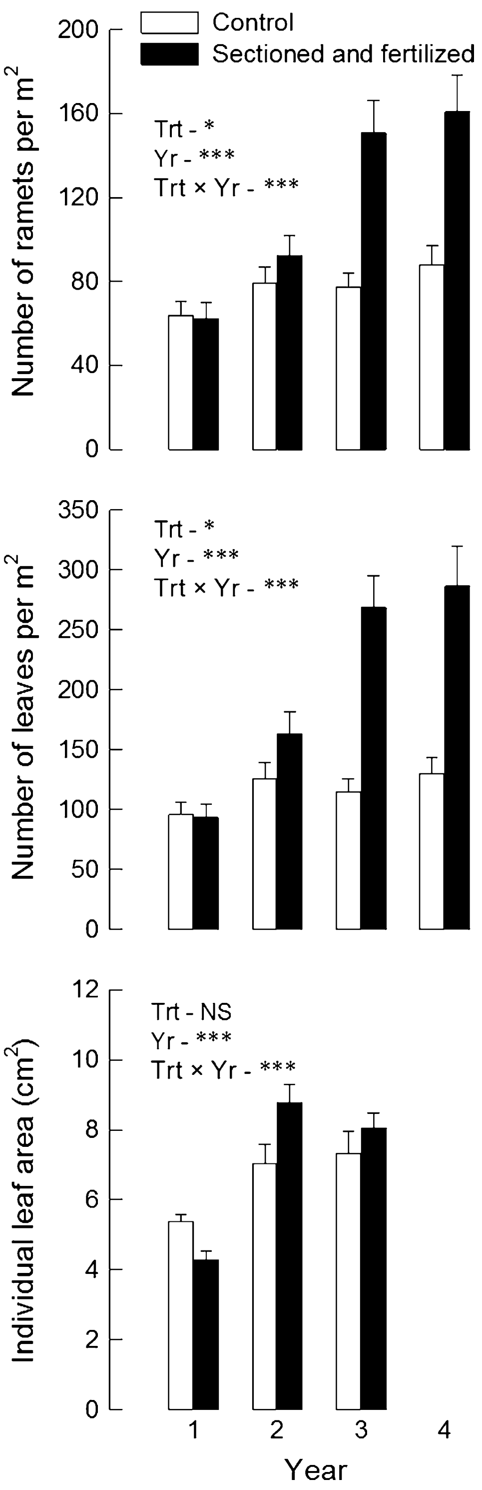

Fig. 1. Number of ramets and leaves per m^2 and area of individual leaves in cloudberry as measured in the middle of the growing season in each year of 4 yr in response to rhizome sectioning and fertilization (LSMeans ± 1 SE; $N=6$). NS, *, **, ***, respectively, indicate non-significance and significance at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$ of the treatment (Trt), year (Yr) and interaction (Trt × Yr) effects.

treatment did not lead to apparent effects on the other plant species growing in the plots (Bellemare 2007).

Flowers and Fruits

The density of female flowers was positively influenced by the combined sectioning and fertilisation treatment (Fig. 2). The treatment × year interaction indicated that annual variations were evident only in sectioned plots, and that the treatment effect became significant only in the last two growing seasons. The increase became substantial between the second and the third years when the number of female flowers more than quadrupled to a total of 23 flowers per square meter. For male flowers, sectioning and fertilizing initially had no effect on numbers. In the 3rd and 4th years, there was a positive treatment effect on male flower numbers; the maximum counted within a single day was 3 ± 1 in control and 5 ± 1 in treated plots in the third year ($P = 0.04$), and 8 ± 2 in control and 33 ± 10 in treated plots after 4 yr ($P = 0.01$). During the second year, the number of flowering ramets having either a male or female flower reached 25 per m^2, which is within the range of 20 to 60 per m^2 reported by Ågren (1988). A delay in the impact of the treatment on flower production was expected because the floral bud of cloudberry is initiated 1 yr prior to flowering (Resvoll 1929). Nutrient inputs could not influence flowering in the first year, as fertilizer was applied late in the growing season. The delay in the response until the third year of the experiment suggests that a build-up of plant reserves was needed before changes in flowering density could be expressed.

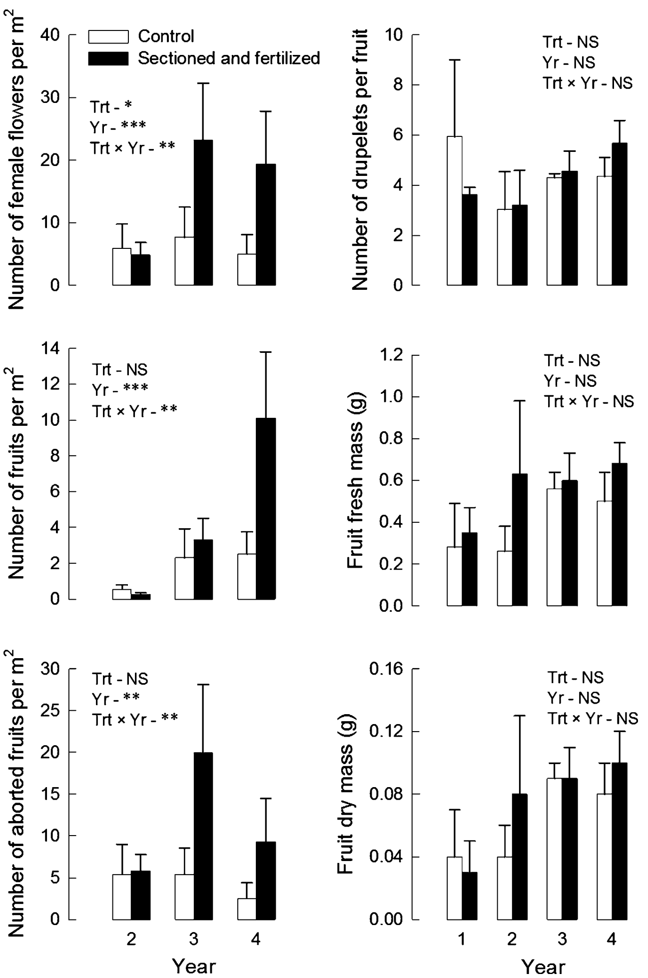

Fig. 2. Number of female flowers, fruits and aborted fruits per m^2 of stand (LSMeans ± 1 SE; $N = 5$), and number of drupelets, mean fresh mass (g) and dry mass (g) per fruit in response to rhizome sectioning and fertilization of cloudberry in each of four years (LSMeans ± 1 SE; $N = 6$). NS, *, **, ***, respectively, indicate non-significance and significance at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$ of the treatment (Trt), year (Yr) and interaction (Trt × Yr) effects.

An increase in the number of fruits was also noted but only 4 yr after the treatment application, as revealed by the treatment × year effect sliced by year, when the number of fruits was almost four times higher in sectioned and fertilized plots than in control plots (Fig. 2). This delayed impact might be explained by the delayed impact on flowers produced but also on the high fruit abortion rates found in the study site (Fig. 2). We observed a higher number of aborted fruits in sectioned and fertilized plots than in control plots, especially in the third growing season as indicated by the treatment × year interaction. Carbohydrate reserves might have been sufficient to increase flowering in the third year, but insufficient to support high numbers of developing fruits as this requires more resources than flower production (Laporte and Delph 1996). During the fourth year, the fruit abortion rate was as high as 60% in control plots and 48% in treated plots. Flower and fruit abortion rates reported in the literature varied between 24 and 51% in cloudberry (Nilsen 2005).

The control plots never produced more than 3 fruit m^{-2}. This is comparable with the range of 0.5–6.4 fruit m^{-2} observed in Scotland (Flower-Ellis 1980), but substantially lower than the finding of 10 to 25 fruits m^{-2} reported from eastern Finland (Mäkinen and Oikarinen 1974). However, the high fruit density observed in the Finish study is similar to our finding of 10 fruits m^{-2} that resulted from sectioning and fertilization in the fourth year. There was also a substantial treatment enhancement of fruit yield in the fourth season, which produced 52.3 kg ha^{-1} compared with 11.5 kg ha^{-1} under control (natural) conditions. In natural peatlands, fruit yield can reach 20 to 50 kg ha^{-1} under optimal conditions that include a peat depth of 0.5 to 1 m, soil pH of 3.5 to 4.5, and a water table 40 to 50 cm below the soil surface (Small and Catling 2000).

Fruits in the study site were relatively small, with an average fresh mass of less than 0.65 g, as compared with 1 to 3 g as found in a more productive peatland (Mäkinen and Oikarinen 1974). Our treatment did not increase fruit fresh mass or dry mass (Fig. 2). The aggregate fruits had fewer than five drupelets on average (Fig. 2), which is low compared with observations reported by Jean and Lapointe (2001; 1 to 14) and Taylor (1971; 4 to 20). At the peatland site we studied, typical flower densities were produced. However, fruit numbers were not as high as those reported in other studies unless rhizome sectioning and fertilisation were applied, and fruits remained relatively small. We demonstrated that the combined treatment of fertilization and sectioning can improve fruit yield in sites such as ours, but other treatments are needed to increase individual fruit size.

As stated, there was an increase in flower density following the treatment application. Mäkinen and Oikarinen (1974) reported that flowering intensity was unaffected by ploughing, which is similar to rhizome sectioning, at one site, but at another site ploughing greatly increased flower number. However, in a study of *Solidago canadensis*, Hartnett and Bazzaz (1983) observed a reduction of flower number in response to rhizome sectioning. As the effect of rhizome sectioning on flower density appears to be site and/or species dependant, more trials are needed to assess this management practice.

Fertilization of cloudberry has been shown to improve flowering and fruiting. An aerial phosphorus-rich fertilization (bird droppings) caused a luxuriant growth and an abundant flowering in cloudberry (Taylor 1971). In Finland, a slight increase in flower production occurred following below-ground nitrogen and phosphorus addition, but there was little effect on fruit production (Kortesharju and Rantala 1980). On the other hand, Lid et al. (1961) showed a positive impact of fertilization with P-K and N-P-K on fruit number and mass. Østgård (1964) found that phosphorus and N-P-K fertilization had an impact on fruit yield in only 2 out of 15 experiments. In fact, fertilisation trials have given only variable and inconclusive results for cloudberry. This suggests that although peatlands are nutrient limited, nutrients might not limit flower or fruit production in cloudberry. Also, the composition of fertilizers tested might not have been targeted specifically toward fruit production. Boron might be a nutrient worthy of focus as it is known to stimulate pollen vitality and increase fruit production in other species such as raspberries (Wojcik 2005).

CONCLUSION

Rhizome sectioning and fertilization enhanced vegetative growth of cloudberry (leaf and ramet densities) beginning the season following treatment, but impacts on production of flowers and fruit were not detected until the third and fourth years, respectively. We reached our objective of improving productivity in natural cloudberry stands by using cultural treatments, but longer-term monitoring may be needed in such studies as the plant response was slow, taking multiple years, and fruit quality (berry mass and number of drupelets) had not yet improved at the conclusion of our study. This study also provided data regarding the natural productivity of cloudberry in North America, as measured in the control plots. As the positive response of the plant to the combination of rhizome sectioning and fertilization could not be attributed wholly or partially to either treatment, the treatments should be tested separately in a factorial experiment.

ACKNOWLEDGEMENTS

We thank Antoine Bernatchez, Olivier Larouche, Claudine Laurendeau and Caroline Mercier for their help in the field, Guillaume Théroux Rancourt and Jin Zhou for their technical assistance, Roxane Andersen for the translation of the manuscript and Julie Bussières for comments and revisions on earlier versions of the manuscript. We appreciate the co-operation of les Tourbières Berger inc. for land use and support throughout the study and the financial support provided by *Le Fonds québécois de recherche sur la nature et les technologies* through the program *Action concertée pour le soutien stratégique à la promotion et à la consolidation de la recherche sur l'environnement rural*, the Natural Sciences and Engineering Research Council of Canada, the Canadian Sphagnum Peat Moss Association and its members.

Ågren, J. 1988. Between-year variation in flowering and fruit set in frost-prone and frost-sheltered population of dioecious *Rubus chamaemorus*. Oecologia **76**: 175–183.

Bellemare, M. 2007. Productivité de la chicouté au Québec en fonction de diverses régies de culture. Mémoire de maîtrise (M.Sc.), Département de phytologie, Université Laval, Québec. 98 pp.

Environnement Canada. 2006. Rapport des données quotidiennes. [Online]. Available: http://www.climate.weatheroffice.ec.gc.ca/climateData/ [2006 Oct. 15].

Flower-Ellis, J. G. K. 1980. Diurnal dry weight variation and dry matter allocation of some tundra plants. 2. *Rubus chamaemorus* L. Ecology of a subarctic mire. Ecol. Bull. **30**: 163–179.

Hartnett, D. C. and Bazzaz, F. A. 1983. Physiological integration among intraclonal ramets in *Solidago canadensis*. Ecology **64**: 779–788.

Jean, D. and Lapointe, L. 2001. Limited carbohydrate availability as a potential cause of fruit abortion in *Rubus chamaemorus*. Physiol. Plant. **112**: 379–387.

Korpelainen, H., Antonius-Klemola, K. and Werlemark, G. 1999. Clonal structure of *Rubus chamaemorus* populations: comparison of different molecular methods. Plant Ecol. **143**: 123–128.

Kortesharju, J. and Rantala, E. M. 1980. The effect of placement fertilization on cloudberry (*Rubus chamaemorus* L.) on unditched bog. Suo **31**: 85–92.

Laporte, M.M. and Delph, L.F. 1996. Sex-specific physiology and source-sink relations in the dioecious plant *Silene latifolia*. Oecologia **106**: 63–72.

Lid, J., Lie, O. and Løddesøl, A. 1961. Orienterende forsøk med dyrking av molter. Medd. fra Norske myrselsk. **59**: 1–26.

Lohi, K. 1974. Variation between cloudberries (*Rubus chamemorus* L.) in different habitats. Aquilo Ser. Bot. **13**: 1–9.

Mäkinen, Y. and Oikarinen, H. 1974. Cultivation of cloudberry in Fennoscandia. Rep. Kevo Subarctic Res. Stat. **11**: 90–102.

Maun, M. A. 1984. Colonizing ability of *Ammophila breviligulata* through vegetative regeneration. J. Ecol. **72**: 565–574.

McIntyre, G. I. 1972. Studies on bud development in the rhizome of *Agropyron repens*. II. The effect of the nitrogen supply. Can. J. Bot. **50**: 393–401.

McIntyre, G. I. 2001. Control of plant development by limiting factors: A nutritional perspective. Physiol. Plant. **113**: 165–175.

Nilsen, G. S. 2005. Cloudberries–The northern gold. Int. J. Fruit Sci. **5**: 45–60.

Østgård, O. 1964. Investigations on cloudberries (*Rubus chamaemorus* L.) in North-Norway. Forsk. Fors. Landbr. **15**: 409–444.

Pauliukonis, N. and Gough, L. 2004. Effects of the loss of clonal integration on four sedges that differ in ramet aggregation. Plant Ecol. **173**: 1–15.

Penney, B. G., McRae, K. B. and Rayment, A. F. 1997. Long-term effects of burn-pruning on lowbush blueberry (*Vaccinium angustifolium* Ait.) production Can. J. Plant Sci. **77**: 421–425.

Rapp, K. 2004. Cloudberry growers guide. North Norwegian Centre for Research and Rural Development., Tromsø, Norway. 15 pp.

Rapp, K. and Steenberg, K. 1977. Studies of phosphorus uptake from different depths in cloudberry mires using ^{32}P-labelled fertilizer. Acta Agric. Scand. **27**: 319–325.

Resvoll, T. 1929. *Rubus chamaemorus* L. A morphological-biological study. Nyt Mag. Naturvid. **67**: 55–129.

Rogan, P. G. and Smith, D. L. 1976. Experimental control of bud inhibition in rhizomes of *Agropyron repens* (L.) Beauv. Z. Pflanzenphysiol. Bd. **78**: 113–121.

Saebø, S. 1968. The autecology of *Rubus chamaemorus* L. I. Phosphorus economy of *Rubus chamaemorus* in an ombrotrophic mire. Sci. Rep. Agric. Univ. Norway **47**: 1–67.

Saebø, S. 1970. The autecology of *Rubus chamaemorus* L. II. Nitrogen economy of *Rubus chamaemorus* in an ombrotrophic mire. Sci. Rep. Agric. Univ. Norway **49**: 1–37.

Saebø, S. 1977. The autecology of *Rubus chamaemorus* L. IV. Potassium relations of *Rubus chamaemorus* in an ombrotrophic mire with some bibliographical notes on *Rubus chamaemorus*. Sci. Rep. Agric. Univ. Norway **56**: 1–20.

Small, E. and Catling, P. M. 2000. Poorly known economic plants of Canada – 27. Cloudberry, *Rubus chamaemorus*. Can. Bot. Assoc. Bull. **33**: 43–47.

Strik, B. C. and Poole, A. 1992. Alternate-year pruning recommended for cranberry. Hortscience **27**: 1327.

Taylor, K. 1971. Biological flora of the British Isles: *Rubus chamaemorus* L. J. Ecol. **59**: 292–306.

Wang, Z., Li, L., Han, X. and Dong, M. 2004. Do rhizome severing and shoot defoliation affect clonal growth of *Leymus chinensis* at ramet population level? Acta Oecol. **26**: 255–260.

Wojcik, P. 2005. Response of primocane-fruiting "Polana" red raspberry to boron fertilization. J. Plant Nutr. **28**: 1821–1832.