MAIN PROJECT
FINAL PROJECT REPORT

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NORTHERN PERIPHERY PROGRAMME SECRETARIAT • STRANDGADE 91, 4 SAL • DK-1401 COPENHAGEN K
PHONE: +45 3283 3784 • FAX: +45 3283 3775
EMAIL: NORTHERNPERIPHERY@NPP2.NET • WEB: WWW.NORTHERNPERIPHERY.NET

1. Executive Summary

The main purpose was to advance the cultivation and use of northern berries, particularly cloudberry while taking into consideration the sustainable use of nature and natural heritage. The project activities included: 1) breeding and selection of best cloudberry varieties; 2) development of mass propagation technique for cloudberry, and propagation of plantlets for the project; 3) adaptation of machinery for soil tilling and cloudberry planting; 4) large-scale cultivation of cloudberry and farmer training in Finland and Norway; 5) cloudberry pest and disease monitoring; 6) experiments on cloudberry pollination; 7) study on the development of normal and parthenocarpic cloudberry fruits; 8) assessing of selected arctic bramble clones for downy mildew tolerance and productivity; 9) monitoring of winter-hardiness and performance of new berry species; 10) analysis of a variety of berry samples for bioactive components and antioxidant capacity. The main final results obtained during the course of the project were:

1) Two Finnish cloudberry varieties were named, i.e. Cloudy and Ruby. Several new cloudberry clones and crosses are ready for production tests.

2) Cloudberry breeding clones were propagated in several different systems: sterile *in vitro* agar culture and temporary liquid immersion; rhizomes in greenhouse. Rhizome method, which is the most economic way of propagating cloudberry, can be transferred to any interested nursery.

3) The machinery adapted to cloudberry planting increases efficacy and lowers the costs of the establishment of new cloudberry fields.

4) Cloudberry cultivation fields were established in Norway and in Finland, and interested growers can go and learn from these model farms. English version of "Cloudberry growers guide" was prepared. A DVD-video "Berries - gold of the north" (25 min) was made including description of some cloudberry cultivation practices.

5) The pest *Galerucella nymphaeae* causes problems on the cultivations, and control systems or insecticides will be needed. Covering the cultivation gives growth benefits by providing wind shield and decreasing temperature fluctuation besides protecting from pest invasion. Pollination experiments in greenhouse suggested that the crop might be increased by placing hives of bumble bees close to the field.

6) Hives with pollinating insects can be used to increase the efficiency of cloudberry pollination.

7) Seedless cloudberries produced during the project may have great commercial potential.

8) A promising downy mildew resistant arctic bramble clone was selected and its propagation started for further studies.

9) Selected plants from *Vaccinium*, *Sorbus* and trailing *Rubus* species have shown to be winter-hardy at Kuopio latitude. Based on these experiments, several new clones and cultivars can be provided for home gardeners and berry farmers.

10) Detailed studies on the phytochemistry of the northern fruits were able to establish an easy and robust assay for the total antioxidant activity. This assay exhibited a direct correlation with the phenolic compounds in the fruit and can easily be used as a breeding tool. In addition, model bioavailability studies showed that a significant proportion of the putative bioactive compounds should survive digestion and get through into the serum. Additional supportive evidence with regard to bioefficacy and health benefits was gained form a feeding trial with a validated human ageing model, the fruit fly. These studies showed that the consumption of cloudberry could retard primary and secondary effects of ageing (lipid oxidation).

2. Introduction and background information on the project's purpose

The Northern Periphery Program regions are rural under-developed areas with sparse population. The farms are small but usually with large unutilised areas consisting of forest, mountains and peatland. In order to be able to make a living from farming many farmers need extra income. Northern climate is unique and provides healthy treasures of the wilderness. Besides exploiting these natural resources, farmers need new opportunities to increase the selection of crop plants suitable for farming. The main purpose of the Northernberries project was to advance the cultivation and use of northern berries, particularly cloudberry which is a native delicious berry of north but has highly fluctuating yield from year to year. Also other berries studied in the project should be particularly adapted to northern harsh climate that in this case represent an opportunity, not a permanent disadvantage.

Large peat bogs have been taken into use by peat industry and forestry, but not always very successfully. Some of the drained areas have not turned out to be productive and efforts are being made to restore them back to peat bogs. The restoration of used peatlands is an extremely slow process in the northern parts of Europe. Our approach to transform used peatlands to productive cloudberry fields supports the sustainable use of nature and natural resources. In addition, used peatlands produce greenhouse gases (lower layers methane, upper layers carbon dioxide). A peatland where the primary production has been restored assimilates carbon dioxide and thereby helps to decrease greenhouse gas emissions from the peatland.

Research and complex network and exchange of experience and good practice in the Northern Periphery area should generate new berry business and trade in an innovative way. The success of the commercialisation depends greatly on the image of the berries. Health image has become an important criterion in the choice of food. The project highlighted this by showing that the berries are rich in compounds that are suggested to provide beneficial effects for the consumers.

From a social and historical aspect it is important to maintain the local traditions in the development of new commercial products, using the knowledge gathered by previous generations about the wild berries. In the global scale, the berries studied in the Northernberries project serve as healthy raw materials for exotic delicacies that are beyond comparison.

3. Description of the project partnership

The lead partner, University of Kuopio (UKU), is located in the core of the biggest berry cultivation area in Finland (mainly strawberry and currants). The group is experienced in studies on arctic bramble, cloudberry and other northern berries (propagation, cultivation, breeding, disease diagnostics, flavonoid analysis). The partner has national collaboration with peat energy producer (VAPO), berry farmer consulting company (Alatalo Co), cloudberry model farmer (Koivuranta Seppo and Raimo/Rasepi Oy) as well as manufacturer and developer of products from northern berries (Riipisen Riistaherkut). Besides working on the cultivation and characterisation of cloudberry and other berries, UKU handled the administration of the project via part-time coordinator (Harri Kokko), dealing with 1) overall thematic activities of the project; 2) administrative and financial affairs raised during the project; 3) web pages; 4) organisation of the trans-national meetings; 5) gathering interim reports from individual partners; 5) progress monitoring against the milestones.

The other partners coordinated the project activities in each country. The tasks included: 1) national thematic activities of the project and progress monitoring against milestones; 2) national administrative and financial affairs; 3) contacts with national project operators and interest groups; 4) organisation of national meetings; 5) preparing interim reports.

Norwegian Crop Research Institute, Holt Research Centre Norway (HOLT), the coordinator in Norway, has 25 years of experience in breeding and growing of wild berries, especially cloudberry. The four cultivars, registered according to the international rules (UPOV), are commercially propagated. The tasks of HOLT were to develop methods for vegetative (using rhizomes) and *in vitro* propagation of cloudberry, study sex differentiation in cloudberry, study fruit and flower development (flower induction by light and temperature), develop a planting machine, cultivate cloudberry and breed new interesting cloudberry varieties. This also included breeding of a stable hermaphroditic clone. HOLT had a subcontract with the University of Tromsø, where a PhD student worked on fruit development in cloudberry, supported by the Norwegian Research Council. In addition, there were subcontracts with the company developing the planting machinery, Enderud Consulting AS, and the propagator Eggen Gartneri who produced all plantlets and rhizomes of the Norwegian cultivars used in the project. Several farmers were involved in a connecting project ("Praktisk dyrking av molte") supported by "Innovasjon Norge". The farmers (10 altogether) are situated in the four northernmost counties in Norway. The purpose was to establish cloudberry fields and to test different cultivation techniques and breeding material. Local berry product industry, "Reisamat", Troms, was present in meetings during the project. Two peat industry partners were active in the project; "Fossli torv" in Nord-Trøndelag and "Andøytorv" in Nordland. The developed planting machinery was tested by the two companies and used for revegetation.

The Scottish Crop Research Institute (SCRI), Dundee, Scotland, has high international reputation in scientific research, particularly including breeding and genetics of small-berried fruits. It has released many successful cultivars of *Rubus* on a global basis. The research group is experienced in studying the bioactive compounds in plants, which was also their role in Northernberries project. SCRI collaborated closely with the Highland Berry Growers Group led by Mr Colin Stirling.

The Swedish partner was Högskoleförbundet Östra Norrbotten (Polytechnical Highschool) (HÖN); also involved from Sweden was the business enterprise Polarica AB. The partner at the State University of St. Petersburg developed a bioassay using fruitfly (*Drosophila*) to test the physiological effects of bioactive compounds, such as antioxidants, from berries.

The network brought together the partners, research organisations, business enterprises, as well as local/regional governments from Finland, Norway, Scotland, Sweden and Northwest Russia. The partners performed both complementary and parallel studies, each concentrating on their strengths. The partners working on various aspects of cultivation were Finland and Norway, with cloudberry varieties adapted to their particular environment. The cloudberry imago as health-promoting food was strengthened by the special analyses performed in Scotland and Russia as well as in Finland. The starting network in Sweden was involved in the information diffusion, research cooperation and commercial exploitation of berries.

4. Starting point of the project

Over 95% of cloudberries are picked from the Northern Periphery Programme area but the commercial cultivation has barely started (only in Norway). The new northern trans-national collaboration, promoted and supported by the Northern Periphery Programme and already started in the "Northberry" project, raised plenty of excitement in the media and contacts from farmers and processing industry. This indicated that the approach in the project had been correct, and encouraged continuing the efforts in the domestication of northern berries. The starting situation was thus very promising considering that the progress thus far had been good.

New promising cloudberry clones had been established, and the propagation methods were significantly improved. In Finland, the original cloudberry collection was largely based on rare

hermaphroditic clones that would eliminate the need for separate male (not producing berries) and female plants in the cultivation. In addition, a significant effort was put in year 2000 on establishing an elite Finnish cloudberry collection based on the competition 'Biggest Cloudberry in Finland'. The best berry from the competition was three times the normal size. In Norway, hermaphroditic clones were used in a breeding program with other Norwegian clones, including clones from the inland and from coastal areas. The cost-efficiency of the propagation and particularly rooting of the plantlets had been markedly improved by *in vitro* culturing techniques developed both in Finland and in Norway. However, a rapid mass propagation system for field trials was still missing. The plant material in UKU and HOLT was to be propagated and planted on field for further selection of cultivars with improved productivity.

Previous experience had shown that the cultivation conditions have to be optimal to promote cloudberry growth and to prevent weeds from taking over. We had planted cloudberry in peatlands on the peat layer where cloudberry's rhizomes normally grow and the water level can be regulated. The natural ecotype of peatland, i.e. the acidic environment, low nutrient level etc. was expected to prevent the overgrowth of weeds. Indeed, no harmful overgrowth had occurred during the first two years. Peat layers do not differ markedly in their nutrient levels, but oxygen availability is poor in the lower, finer and more condensed layers. This problem had to be solved before the peatlands could be fully exploited for cloudberry cultivation. The aim was to improve the soil texture by mixing in e.g. straw. We had also started experiments on straw mulch in a hope to be able to delay cloudberry flowering in North-Savo area and, thereby, to protect the flowers from spring frosts. The cloudberry cultivation trials had progressed to flowering and fruit setting stage. The productivity (covering rate and extent, number of flowers, pollination efficiency, yield etc.) was to be followed in order to predict the commercialisation potential. Quality of berries needed to be analysed.

Large-scale technology was needed. Machines had been tested for large-scale pre-treatment of peat (tilling, fertilization, mulching etc.) and planting, but effects on cloudberry cultivation needed to be analysed. 'Synthetic' populations of pollinators were to be tested in Norway.

Arctic bramble clones with potentially improved downy mildew resistance had been selected. Ten arctic bramble clones had been chosen among over 200 clones during 2-year trials in the botanical garden of the University of Kuopio. The downy mildew tolerance and performance (yield and other agronomic characteristics) needed to be confirmed under normal cultivation conditions before the commercialisation.

There is a continuous interest for new small fruit crop varieties adapted to harsh climate conditions. Some plants had already preliminarily been tested in mini-scale in Pohjois-Savo (Finland), e.g. 7 varieties of Saskatoon (*Amelanchier alnifolia*, Juneberry, origin: Canada) with very early fruiting; sweet rowanberries (*Sorbus* spp and hybrids; origin: Estonia, Russia) with great potential for processing industry; 'trailing very early red blackberry' (*Rubus* with unknown pedigree, from Russia?). Berries were to be collected from these plants for the analysis of bioactive components.

There were several studies suggesting that berries contain compounds with health-promoting and disease-preventing properties. Preliminary studies by our Russian partner with Finnish cloudberries had shown that the juice was the strongest antioxidant (prevented lipid peroxidation), more effective than anything else they had ever tested (including potential medicines). This study was done with a unique animal model (*Drosophila*). Our Russian partner was to extend this study to examine the effect on the lifespan of the animal (Tacis funding was to be applied). The importance of this study, if successful, was to provide further evidence of the health benefits of the berries and increase the demand and markets for beneficial berry products. The same aim was in the studies where the content of bioactive compounds was to be analysed from various berries grown in the northern climate.

5. Intended aims and objectives

The aim was the advancement of the cultivation and use of northern berries, particularly cloudberry, while respecting the sustainable use of nature and natural heritage. The enhancement of cloudberry business and studies on the potential of other berries and their health-related compounds were divided into the following objectives:

1) breeding and selection of new cloudberry clones;
2) development of cloudberry propagation techniques;
3) development of machinery for cloudberry planting;
4) cloudberry cultivation trials on peatland, disease monitoring and farmers' training;
5) cloudberry pollination studies;
6) study on cloudberry fruit development;
7) improvement of quality and productivity of arctic bramble through selection of downy mildew tolerant clones;
8) monitoring of winter-hardiness and performance of new berries of *Amalanchier, Vaccinium*, *Sorbus* and *Rubus*;
9) analysis of a variety of berries for their bioactive components;
10) studies on antioxidant capacity of northern soft fruits.

6. Project's activities and results

A detailed description of the project's activities and results is given below, reflecting the milestones and deliverables set in the application. The numbers A1 to A13 refer to the project's main stages 1 to 13. Included are also the expected results E1 to E10, corresponding to the respective numbers 1 to 10 in the application.

A1: Overall coordination (UKU)

UKU took care of the administration of the project with the help of part-time coordinator (Harri Kokko), dealing with 1) overall thematic activities of the project; 2) administrative and financial affairs raised during the project; 3) web pages; 4) organisation of the trans-national meetings; 5) gathering interim reports from individual partners; 5) progress monitoring against milestones. All thematic activities proceeded as planned. All administrative and financial affairs raised during the project were solved bilaterally. Web pages were prepared and updated (www.uku.fi/northernberries). Trans-national meetings were organised in Inverness (Scotland; 4-5.11.2002), Tromso (Norway; 24-25.8.2003) and Kuopio (Finland; 22-24.8.2004). A collaborative meeting with Canadian researchers was organised in Kuopio (12-13.8.2003). Progress monitoring against milestones was discussed during every meeting. Five progress reports and nine financial reports as well as final report with audition were delivered.

A2: Mass propagation of cloudberry (UKU, HOLT, nurseries)
E 2. Cloudberry nursery production commercialised in Finland

UKU: Mass propagation of selected cloudberry clones for Kuusamo and Karttula test fields was performed using temporary liquid immersion system (RITA). This micropropagation method was effective but rooting of the propagated material needs more optimization before the plants can be produced cost-effectively. The most economic way of plant production appeared to be through rhizomes in the greenhouse or in open peatland.

HOLT: The *in vitro* culture of cloudberry works well for research purposes. A paper describing the method was published in an international refereed journal (Martinussen *et al.* 2004). This is the first paper describing *in vitro* propagation of cloudberry and thus has potentially a great impact. The paper points out the challenges in commercialising the method, and the results provide a good basis for further optimisation. All cloudberry plant material produced for commercial purposes are, however, done through rhizomes. This method was further improved during the project.

Nurseries: Cloudberry nursery production has started in Finland. The (micro)propagation knowledge has been transferred to Biotaimi Ltd. (nursery, SME partner in Finland). The first greenhouse growing experiments have been done in Muuruvesi, Finland.

A3: Model cloudberry farm: large-scale cultivation and farmer training (UKU, HOLT, HÖN, farmers, peat industry)

UKU, farmers, peat industry: Cloudberry cultivation experiments were performed in peatland in Kuparivaara Kuusamo (Rasepi Oy) and Karttula (Vapo Oy). The large-scale cultivation trials were established in Kuusamo in autumn 2002. The first cultivation test area (~0,6 ha) was established by fertilizing the cloudberries with three different treatments. Water levels were adjusted to three different levels by embanking the ditches of the test area. The second cloudberry cultivation area (~0,6 ha) was set-up in Kuusamo in autumn 2003 by using cloudberry seeds obtained from jam processing waste. The effects of different fertilization treatments and watering on the crop potential and growing of seedlings were evaluated during 2003-2005. In summer 2005, the positive effect of fertilization on the yield was very

large and statistically significant (ANOVA/Tukey test), five to ten times more berries being picked from the best sample plots (Figure 1). The most serious threat to cloudberry in field and cultivation conditions is the cloudberry leaf beetle *Galerucella sagittariae.* This pest was controlled with special netting in the Kuusamo test fields. Since the spring frost easily destroys cloudberry flowers, covering the cultivation with a special material was tested in Kuusamo during the summer 2005. Despite the absence of spring frost, the results were very promising, since the cover gave wind protection and shaded the plants from direct sun. The plants under the cover were more vigorous and green at the end of the summer.
The use of peat for energy production has been of great importance in northern Finland, but the Kioto climate agreement has put peat energy production in a new situation because of the taxation. The reuse of peatland after energy production for cloudberry cultivation was one goal in Northernberries project. Natural reappearance of *Sphagnum* mosses and cloudberry in cut-away peatland is a slow process, and also the growth of planted cloudberries in these areas is impeded. The restoration of used peatland was tested in Karttula, Finland, small areas being covered by *Sphagnum* moss. Two common companion mosses of cloudberry, i.e. *S. magellanicum* and *S. fuscum* as well as *S. angustifolium* were selected and isolated for revegetation studies started in Petronneva bog. Preliminary results suggest that the straw mulch cover on the peat surface and revegetation with *Sphagnum* mosses will help spreading of the planted cloudberries and establishment of dense cultivation.

Training of farmers was taking place in the form of seminars and guidance in the test fields and peatland areas. The results of the Northernberries project have also been presented in several seminars and meetings for students and other contact persons. Practical guidance of cloudberry farming has been collected to a DVD video "Berries - gold of the north" produced during the project.

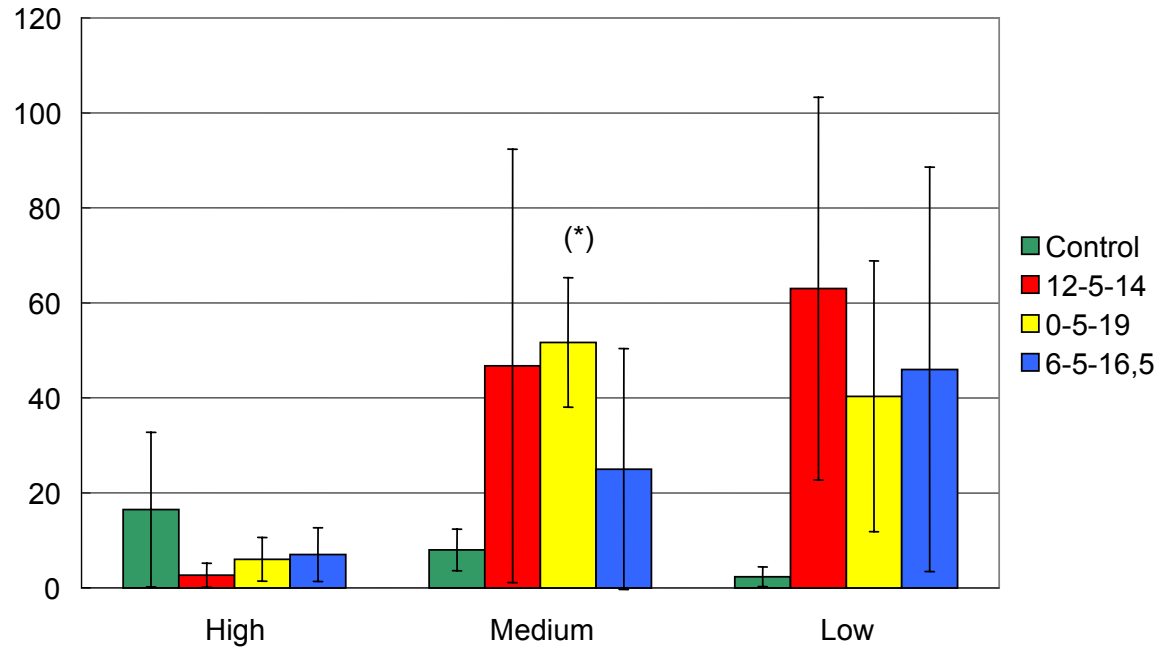


Figure 1. Effect of different fertilization treatments on cloudberry crop (berries/plot) at three watering levels.
Soil surface above the water level was either high (50-80 cm), medium (30-50 cm) or low (20-30 cm).
The test plots were fertilized with 50 g/m^2 of various N-P-K mixtures (%; see the colour codes on the right hand side).

HOLT, farmers, peat industry: Originally, one farmer from each county (four altogether) was expected to participate Northernberries project. However, from the very beginning only the two peat industry partners have grown cloudberries as active partners in this project. All other growers are connected to Northernberries via the project “Praktisk dyrking av molte”. The challenges in implementation of this activity are the different types of peatlands (humification degree, geography, climate, etc.) and that the different farmers have different ambitions. Seminars have been given in different regions within the four northernmost counties in Norway. All farmers involved in model cloudberry farming have been given the opportunity to join these annual courses.

All parties gave guidance to farmers during the project.

A4: Development of new machinery for planting and soil cultivation (HOLT, Enderud)
E4. Machinery tested for its suitability for large-scale cloudberry cultivation

Planting machinery has been adapted to cloudberry and tested in Norway with industrial partners. The development of the machinery was very successful. It has turned out to be well-suited, with adaptations, to different kind of peatlands (Figure 2). It is very useful for revegetation of open peatland and for large-scale cloudberry cultivation. The machine decreases the initial costs of establishing a cloudberry field, and gives the opportunity for fast revegetation of stripped peatland. The planting machine is now at the Holt Research Station and can be used for planting of plantlets and rhizomes of companies and farmers in the whole Northern Periphery Region in Norway. The machine also serves as a prototype for new planting machines. The sub-contractor was changed from SINTEF to Enderud Consulting AS because of the high cost of the first sub-contractor. However, testing of the machinery by the peat industry went very well, since both companies are well experienced in engineering.

Figure 2. Planting machine was used for establishing cloudberry cultivation in Norway

A5: Selection of best varieties: performance of cloudberry clones (UKU, HOLT, farmers)
E1. First commercial hermaphroditic cloudberry variety described

UKU: Cloudberry breeding efforts continued throughout the whole project. Several hundreds of seedlings have been grown from the breeding material. These have been evaluated in greenhouse and test field conditions, and new cultivars can be selected from this material in the future. The first two Finnish cloudberry varieties were named "Cloudy", which is hermaphroditic, and "Ruby", which has red coloured berries (tested in the *Drosophila* animal model). "Cloudy" can be maintained as hermaphrodite by *in vitro* or rhizome propagation. Seeds grown from this clone are either hermaphrodites (rather small percentage), males or females. This suggests that the clone is not homozygous for this characteristic or that hermaphroditism is a quantitative trait that inherits in a complex manner. So far the clone has not been commercially available since commercial cultivation of cloudberry has not yet started in Finland.

HOLT: There is a continuous search for better varieties of cloudberry, especially a stable hermaphroditic clone and clones adapted to southern parts of Norway (the four available varieties are adapted to northern parts of Norway). So far there has been no success in

finding a stable hermaphroditic clone from Norway, since after some years all clones turned out to be males. This can be explained by the findings obtained from the studies on flower development and sex differentiation. These studies suggest that the hermaphroditic clones are developmentally closer to the males than to the females.

A6: Cloudberry disease monitoring (UKU)

The diseases of cloudberry were monitored in the nature and test fields, but symptoms were low and no black spot disease was detected during the project. A quantitative PCR method was developed for the analysis of possible downy mildew (*Peronospora sparsa*) infections in cloudberry. A sensitive and specific screening method was achieved. The method enables the selection of tolerant clones and monitoring downy mildew infections in cloudberry cultivars or natural populations.

A7: Arctic bramble: quality and productivity of selected downy mildew tolerant clones (UKU)
E5. New arctic bramble clones verified for downy mildew resistance

One strong candidate for downy mildew tolerant arctic bramble
Selection of new downy mildew tolerant/resistant arctic bramble clones continued during 2002-2005. The test field evaluation of downy mildew resistant candidate clones was performed and one clone was selected for future cultivation trials. The spread of disease and symptoms of downy mildew in the foliage was followed in the test field of Kuopio in 2003-2004. All berries from the test clones were collected in 2004 and classified to two groups: 1) fully developed, and 2) undeveloped and dried berries. The most important characteristics for the selection of the most promising clone were yield and the ratio of fully developed to dried berries (Figure 3).

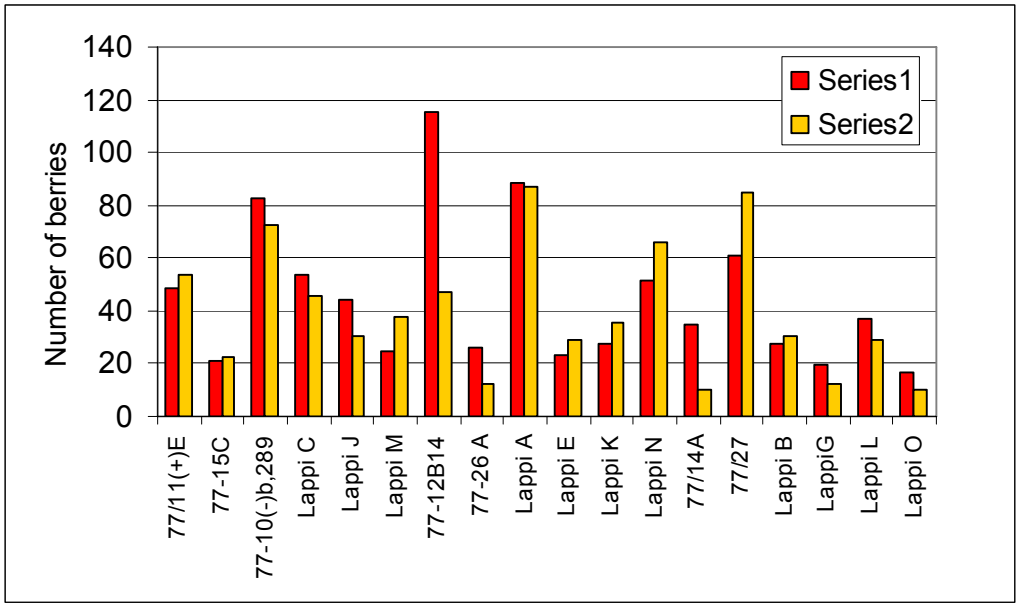


Figure 3. Yield of arctic bramble clones tested for downy mildew resistance in Kuopio in 2004. Total number of berries in each test plot (one test clone in each plot); fully developed berries (series 1) and undeveloped and dried berries (series 2).

A drawback is that there is only one strong candidate that appears to be resistant to downy mildew. Since arctic bramble is self-incompatible (cannot self-pollinate), at least two different clones need to be planted in the field. This is thus a possible source of problem, and further

efforts are needed to find or develop other disease resistant arctic bramble clones. Meanwhile, the problem may be overcome by giving the plants a treatment that protects them from the disease. Therefore, as an additional activity, several elicitors capable of inducing disease resistance in plants were tested against downy mildew in arctic bramble. These experiments were based on the experiences obtained with strawberry.

Powdery mildew in strawberry as a model for induced disease resistance

As a model system of induced resistance in *Rosaceae* plants, some experiments were performed with strawberry and powdery mildew under greenhouse conditions. This part of research was supportive to the arctic bramble experiments. Bion® provided excellent protection against powdery mildew in strawberry, decreasing infections at least by 50% (Figure 4). Laboratory methods were tested to analyze the induction of resistance by Bion®, for example the analysis of signalling compound salicylic acid and phenolic secondary metabolites. Those methods are directly applicable for the analysis of arctic bramble. Both plant species, strawberry and arctic bramble, belong to the *Rosaceae* family, thus assumingly expressing similar type of defence reactions. Biochemical defence is, however, largely unknown in the *Rosaceae* species. The results obtained here can be utilized in designing plant protection, for example in choosing compounds capable for activating the most efficient defence pathways in *Rosaceae* berry plants. Furthermore, the results of strawberry experiments were utilized in the planning of experiments on arctic bramble. The results have been presented as a poster in the Joint Workshop of PR-proteins and Induced Resistance in Denmark in 2004.

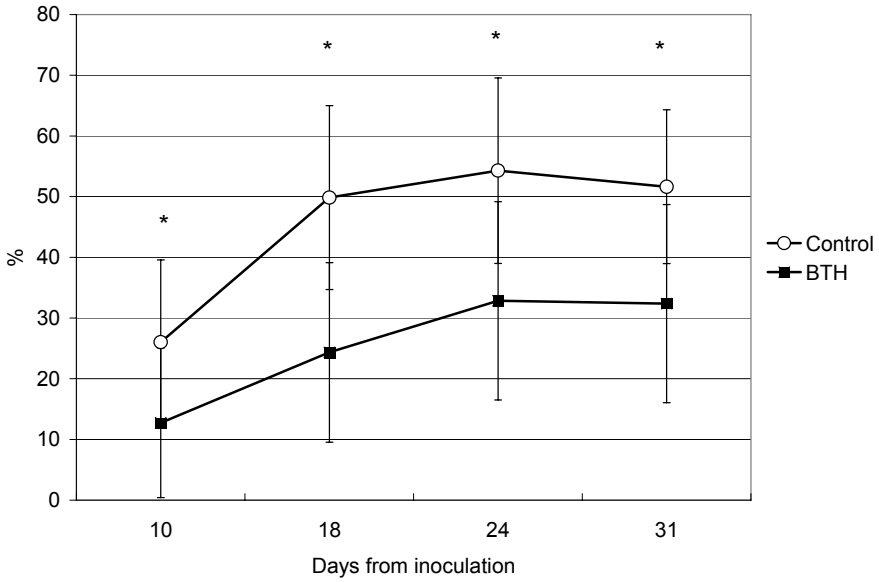


Figure 4. Percentage of infected strawberry plants (%) among water (control) or Bion (BTH) treated plants inoculated with powdery mildew conidia.

Testing of treatments that might protect arctic bramble from downy mildew infection
Several compounds (monopotassium phosphate; Farm-Fos-44® containing potassium phosphite; Bion®) were tested in three experiments for two downy mildew susceptible arctic bramble cultivars at the University of Kuopio in 2003-2005. Aliette 80 WG was used as a positive control; it is a registered systemic fungicide for arctic bramble. Water was used as the negative control. Firstly, the compounds were tested under greenhouse conditions in 2003 to determine suitable application rates. Secondly, the experiment was carried out under field conditions in 2004 and 2005 with plants planted in 2003. The plants were treated 5-7 times in June, and downy mildew symptoms, growth and yield parameters were measured. The growth of the plants in 2004 was poorer than on average, resulting in smaller plants than

expected, and the results need to be interpreted with caution. In 2005, on the other hand, the growth was more vigorous. Therefore, the assessment was mainly based on these treatments. A large number of new shoots grew later during the same season and gave a second crop, which was evaluated separately from the first one. There were two months between the last treatments and the second crop. Thus the influence of the compounds tested against downy mildew infection was, for obvious reasons, small on this second cropping in August and September.

Among the compounds tested, the most promising appeared to be Farm-Fos-44®. It was tested both in a commercial berry farm and in the University of Kuopio. The farmer in Karttula used Farm-Fos 44® during two consecutive years. Based on his previous long experience the farmer estimated that Farm-Fos 44® was beneficial against downy mildew, less symptoms and higher ratio of good quality berries being observed. No exact measurements were made from this trial. Under more rigorously controlled conditions in the University of Kuopio, Farm-Fos-44® did not prevent downy mildew infection or increase yield significantly. However, it had small positive effect on the vegetative growth of plants (13%) (Figures 5 and 6). Potassium phosphate treatment did not increase vegetative growth or yield and, in cv. Pima, these were inferior to those in the control plants. Further, the highest number of downy mildew symptoms was observed in this treatment, implying that potassium phosphate cannot be recommended against downy mildew in arctic bramble. In general, phosphates had more positive effects in cv. Mespi than in cv. Pima. For both potassium phosphate and potassium phosphite (Farm-Fos 44®), the concentration should be carefully adjusted, since even a slight increase, particularly in phosphate, results in phytotoxic symptoms in arctic bramble.

Bion® had a negative effect on vegetative growth in both cultivars, decreasing the weight by 20-30%. On the other hand, it had a positive effect on yield, particularly in cv. Pima, increasing the yield up to 10% compared with the control treatment. In fact, only Bion® treated cv. Pima gave a better yield than did the control plants. Bion® was also combined with potassium phosphate in one treatment, and this combination gave the best yield in cv. Mespi (increase ca. 100%). Bion® decreased downy mildew symptoms in the berries of cv. Pima and, combined with potassium phosphate, also in cv. Mespi, in the first crop in 2005. The compound had no effect on the symptoms in the leaves during the late season compared with those in the control plants treated with water. Aliette 80 WG had no major effect on growth, yield or downy mildew symptoms.

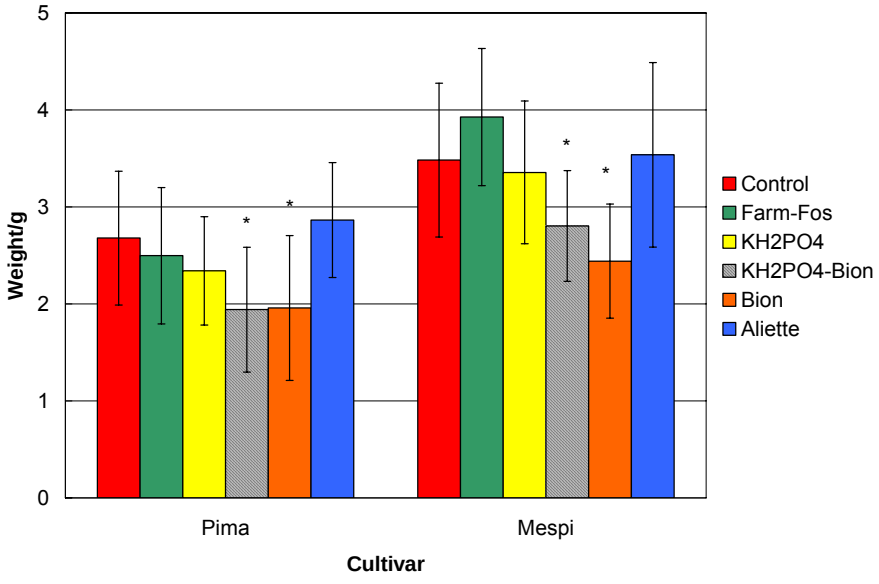


Figure 5. Effect of various treatments on the biomass (dry weight) of arctic bramble shoots in September 2005.

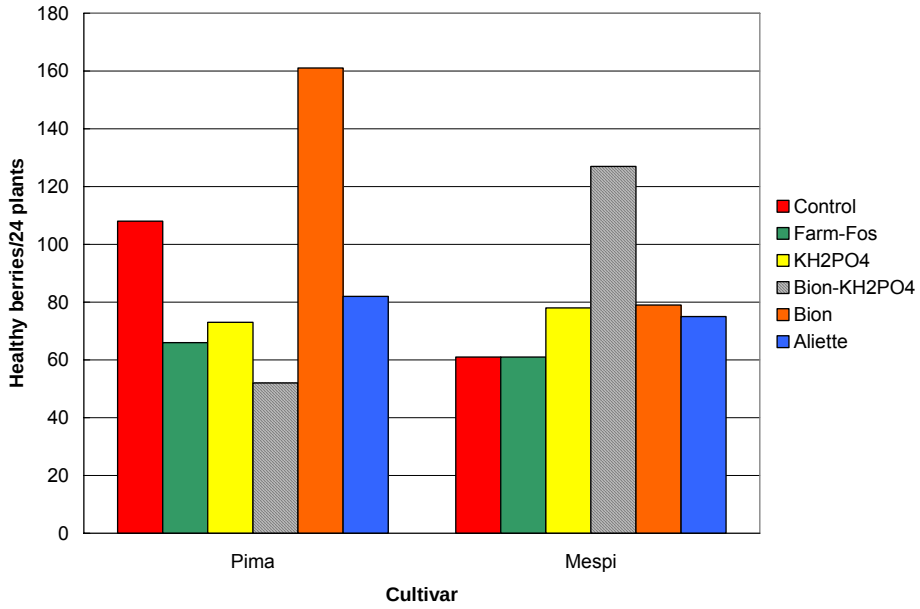


Figure 6. Effect of various treatments on the number of healthy arctic bramble berries in 2005. 24 plants were pooled together, and the 1st and 2nd crop was combined.

These experiments support the original objectives, providing an alternative strategy to protect arctic bramble from downy mildew. Elicitors such as Bion® tested preliminarily in the project can be used together with tolerant arctic bramble clones, thus assuring satisfactory protection against downy mildew. These experiments did not result in complete solutions for growers but, among the tested compounds, particularly Farm-Fos-44® can be a potential new compound for protection of the arctic bramble cultivations.

Sensitive method for the identification and quantification of downy mildew

As an additional activity, a sensitive method based on modern molecular biology (quantitative PCR) was successfully developed for the analysis of the presence and amount of downy mildew (*Peronospora sparsa*) in cloudberry and arctic bramble. The goal was a method that would be applicable for the analysis of *Peronospora* infections in several important cultivated plant species belonging to *Rosaceae* family, for example rose, strawberry and *Rubus* species, including arctic bramble, cloudberry, raspberry and boysenberry. Downy mildew fungus does not grow outside living host plants, and the disease monitoring has been based only on visual symptoms, which can be affected by cultivar and environmental factors. Thus reliable quantification method was necessary for the evaluation of downy mildew infections. Arctic bramble leaves of different ages and symptoms were analysed for their *Peronospora* content. In cv. Pima, the highest amounts of *Peronospora* DNA were found in the youngest leaves (1.5% *Peronospora* DNA in total DNA), the amount of symptoms correlating with the level of fungus. However, in cv. Mesma, the leaves of which showed very strong symptoms, no *Peronospora* was found. These results indicate that the assessment of disease resistance cannot be based solely on symptoms in the leaves. With this new method, evaluation of tolerant clones and breeding material as well as the efficacy of various treatments will be possible without the dependency on leaf symptoms which are variable and do not give a clear indication of the amount of downy mildew in the plant. Work and cost savings can be obtained, when the actual level of infection is known. The method is also suitable for strawberry and rose samples. A draft manuscript has been prepared and is soon ready for submission to a scientific journal. The method and results obtained so far are important for further search and development of resistant clones and disease management.

Isolation and in vitro *cultivation of downy mildew fungus* Peronospora sparsa

As an additional activity, pure culture of *Peronospora sparsa*, the causative agent of downy mildew disease, was isolated from sporulating arctic bramble in 2005. Previous attempts failed, making this a breakthrough for more controlled analyses of tolerant clones and breeding material of arctic bramble. It enables controlled inoculations and pre-screening of downy mildew tolerant arctic bramble clones before large-scale field experiments. Plant protecting compounds and elicitors can also be assessed in controlled experiments. The culture system of downy mildew fungus supports directly the original goal of finding tolerant clones and testing them reliably. *In vitro* testing, which is enabled by controlled inoculations with *Peronospora*, saves time and labour and thus costs of further research.

A8: Winter-hardiness and performance of new berries (UKU, HÖN, farmers)
E6. Information of the cultivation potential of new berry species

Besides cloudberry and arctic bramble, a few other plant species were tested during the project. Blueberry breeding continued throughout the whole project in UKU. To find more winter-hardy and better adapted blueberry clones, seedlings have been planted to the selection field in Kuopio between the years 2002-2004. This material is now under evaluation for cropping, yield quality and winter-hardiness. HÖN and Polarica started a project "Domestication of bilberries" (doctoral student Andreas Åkerström) in which the knowledge base of the Northernberries partners has been exploited. Colin Sterling from Highland Berry Association contacted the University of Oulu through UKU to receive bilberry planting material for experimental fields in Scotland.

All sweet rowanberry (*Sorbus* and hybrids) varieties turned out to be winter-hardy in Kuopio region. The world's largest sweet rowan farm, located in Koijärvi, Finland (Hannu Jaakkola), is based on the experience gained in UKU. Active cooperation between the farmer and UKU has continued during Nothernberries project. The farmer has also supplied these berries for product development tests in local enterprises, and also distributed information of the cultivation and berries. Another sweet rowan cultivation of 1.2 hectares has been established in Kuopio in spring 2005. A development project was done by Vesa-Matti Lintunen from Savonia Polytechnic, Iisalmi on "Starting sweet rowan cultivation according to agricultural subsidy conditions"; Harri Kokko was interviewed to this project. Sweet rowans grow in different forms and have also raised interest for use in landscaping.

Growing of saskatoon (*Amalanchier alnifolia*) has been successful in Kuopio area (UKU; Karhunen, Karttula) but also in Kuusamo (Timo Alatalo) and Tromso (Mo Planteskole). The winter-hardiness and early ripening of saskatoon berries make them potential new berry plants for private gardens throughout the Nordic countries. The berries seem to attract birds and, therefore, crop protection by netting is needed.

The trailing *Rubus* species set berries in Kuopio in 2004 and 2005, but in the test field some winter damages have been observed and, therefore, cultivation and fertilization techniques have to be optimized before the commercialisation of any varieties. A small number of test plants have been planted in an arctic bramble farm (Karhunen, Karttula).

More details about the potential of these berries are provided in the DVD video "Berries - gold of the north" (speak in English and Finnish).

A9: Berry collection for the analysis of bioactive components (UKU)

Berries have been collected from all plant species under study in the Northernberries project and sent to SCRI for the analysis of antioxidants. The main focus was in cloudberry, and also some cloudberry products were analysed. The results show that these berries are high in antioxidants. As an additional task, samples of berries from Norway were also sent to SCRI for analysis (cloudberry and crowberry). However, the budget limited the possibilities to analyse these berries within this project.

Sweet rowanberries have been sent to two small companies (SME) for jam processing (Alahovin Viinitila, Kuopio; Riipisen Riistaherkut, Kuusamo). Juices of rowanberries have been sent for testing as food ingredients to Kasvisgalleria (Kuopio), Lihaniekka (Kuopio) and Apetit (Kalatukku, Turku) in fall 2005. Rowanberry samples have also been sent to Kiantama Ltd. (Suomussalmi) to test a drying process of frozen berries. The results of these tests are not yet available.

A10: Basis of antioxidant capacity in northern soft fruit (SCRI)
E7. Profiles of phenolic and antioxidant compounds of several berries

The success of the commercialisation of the berries depends greatly on their image. For an increasing number of people, health image has become an important criterion in the choice of food. The project approached this by developing indicators for the beneficial effects of the berries. Berry samples were analysed both in Scotland and in Finland. The planned activities were to 1) prepare juices and optimised antioxidant extracts; 2) profile vitamin C, anthocyanin and phenolic compounds; 3) determine antioxidant capacities in *in vitro* systems; 4) grow selected (sub)species in glasshouse and growth cabinet for detailed analysis and biological (*ex vivo*) testing; and 5) determine antioxidant capacities of selected subspecies in biological systems.

All deliverables were achieved. Selected rowan, blueberry and *Rubus* cultivars from the partners in Finland and Norway as well as other Scottish derived soft fruits (*Rubus*, *Ribes*, *Fragaria*) were harvested and 100% juices and optimised antioxidant extracts were made. The basis of the relationship(s) between the antioxidant capacity (AC) of both the juices and extracts was studies and, over *ALL* species, a direct relationship between AC and total phenol, and to a lesser degree anthocyanin, contents was established (Figures 7 & 8). This direct relationship was stronger (R^2 >0.9) for the TEAC and FRAP AC values of optimised extracts. The values for the relationship of the 100% juice TEAC and FRAP AC values were weaker with R^2 values of 0.7 and 0.6, respectively. There was no relationship between antioxidant capacity and vitamin C content, even in *Ribes* and high vitamin C containing rowan cultivars.

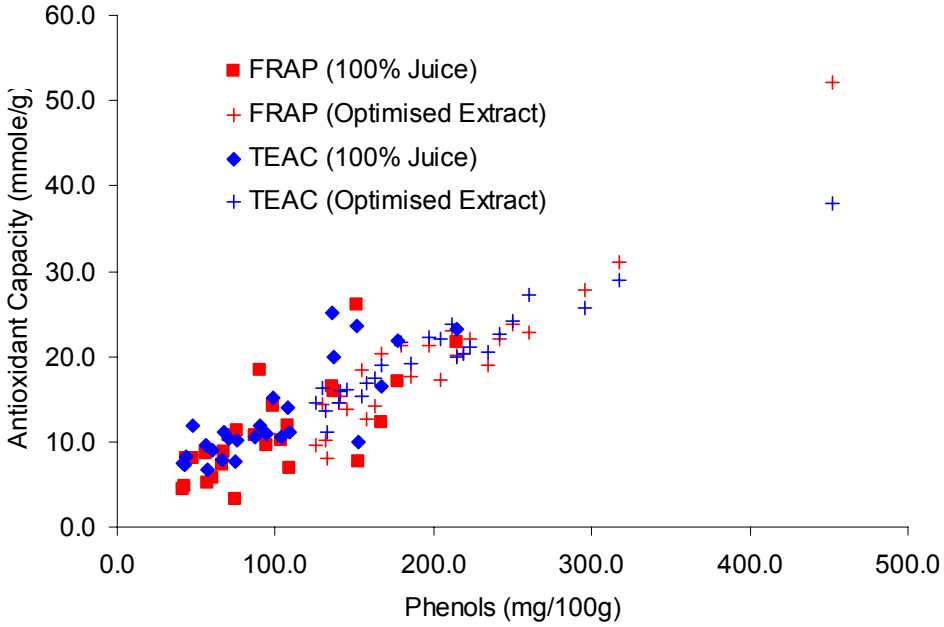


Figure 7. The relationship between antioxidant capacity (TEAC and FRAP) and the phenol contents of pure (100%) juice and optimised (1:1, fruit to acidified acetonitrile) fruit extracts.

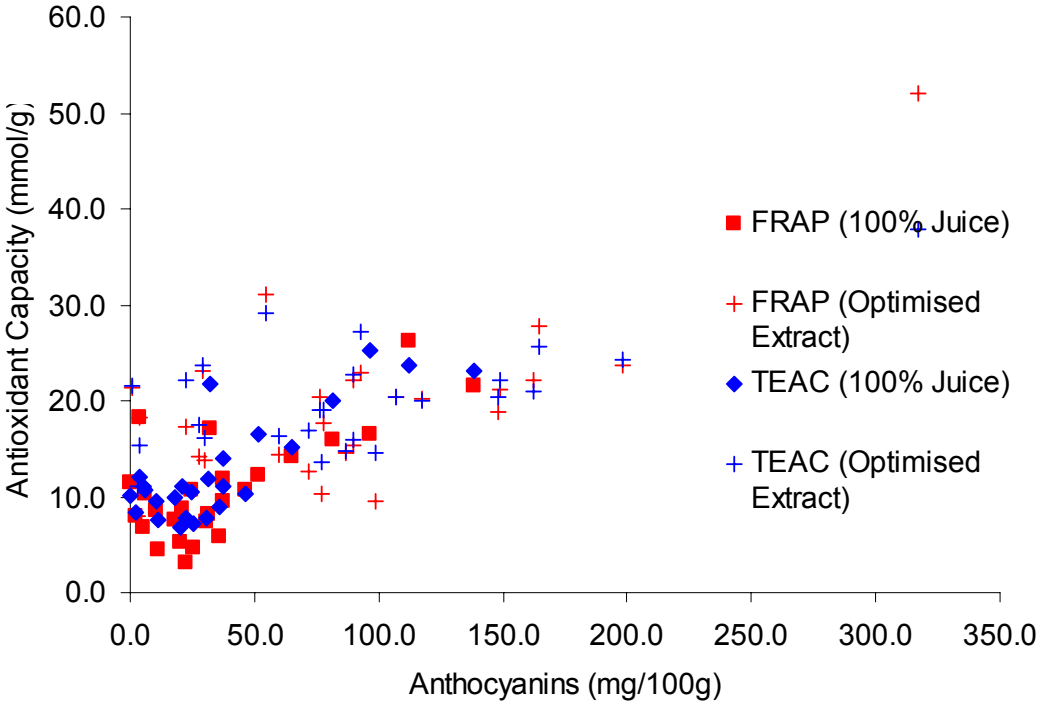


Figure 8. The relationship between antioxidant capacity (TEAC and FRAP) and the anthocyanin contents of pure (100%) juice and optimised (1:1, fruit to acidified acetonitrile) fruit extracts

To determine the *in vitro* bioavailability, a testing method was developed based on the method of Miller *et al*[1]. This method was successfully used to study the bioavailability of iron in the diet, and its relevance has subsequently been validated by human *in vivo* studies. Its use reflects the necessity to have an intermediate step between classical antioxidant analysis and mammalian *in vivo* studies that is both relevant to the *in vivo* systems whilst still allowing the phytochemical diversity and synergy of soft fruit antioxidants to be explored and analysed.

This method showed that there was a significant variation in the stability of the phenolic antioxidants following *in vitro* digestion, and that all compounds experienced degradation to varying degrees, ranging from 10-5% total phenolic compound recovery. The rowan cultivar Sahharnaja exhibited (marginally) the best phenolic bioavailability (availability of phenols to be taken up into serum) when all samples were studied on a % of the initial amount added. However, inter and intra species variation of the total phenol content was significantly large which meant that, although the rowan phenolics survived the *in vitro* digestion marginally better than the others, the total contents were significantly less than for other species (rowan<lingonberry<cloudberry<<blackcurrant).

Furthermore, detailed studies into phytochemical bioavailability suggested that the stability of individual polyphenolic components, like anthocyanins (red cloudberry) or ellagitannins (red and yellow cloudberry), may be greatly influenced by the polyphenolic composition of fruit extracts, perhaps due to sacrificial protection by more labile components. Therefore, simple stability-structure relationships between polyphenol classes, within individual polyphenol classes and for structural attributes like the type or number of glycosyl linkages may not be easily obtained or indeed be valid. Although further work on purified components is required to define degradation pathways and products, this finding re-affirms the importance of examining complete fruit extracts or the final product.

An *in vitro* method was established to determine the potential of fruit, juice extracts and compounds to retard and/or alleviate the onset/progression of atherosclerosis. This method is based on the initial stages of atherosclerogenesis which involve the oxidation of Low Density Lipoprotein.

Oxidation experiments were performed using cupric ion [Cu^{2+}] as the free radical oxidant (FRO), and the antioxidant (fruit juice etc.) was pre-incubated with LDL prior to the exposure. The oxidation of LDL was followed, and the efficacy of the antioxidant to inhibit oxidation was determined for a given time. Three species were tested, *Rubus* (inc. cloudberry), *Ribes* and *Fragaria*. The first set of experiments was done on equivalent vitamin C content basis, and they showed that vitamin C content increased in the order *Fragaria*<*Ribes*<*Rubus*. However, the vitamin C levels vary significantly between these species and so does the phenol content. Consequently, the same experiment was done on equivalent phenol content basis and this yielded the following efficacy ranking: *Ribes*<*Fragaria*<*Rubus*. This protective antioxidant behaviour of *Rubus* species was further corroborated *in vivo* by feeding experiments with a lipid oxidation model system, *Drosophila melanogaster* (fruit fly) (See E8 below).

In addition to the studies into cloudberry, research was also focussed at sea buckthorn. The sea buckthorn industry in Europe exports 100,000 kg of berries per annum (www.itmonline.org.arts/seabuckthorn) to the rest of the world, and with plantations established in Canada, USA and China - to name but a few – the industry is expanding by the day. The only way that sea buckthorn from the Northern countries can compete is by offering something new or supply to local (national) consumers. Although some of the theories for sea buckthorn's healing properties may be unsupported, there is an abundance of evidence

[1] Miller, D.D., Schricker, B.R., Rasmussen, R.R. & Van Campden, D. (1981). An *in vitro* method for estimation of iron availability from meals. *Am. J. Clin. Nutr.* 34, 2248-2256.

proving that these berries do have beneficial properties with regards to human health. As well as having large amounts of vitamin C and E, they are rich – second highest content only to palm oil - in a group of compounds called carotenoids. Carotenoids give the berries their characteristic yellow colour as they have conjugated chains (i.e. long chain of alternating double bonds) which absorb the green/blue part of the spectrum reflecting a yellow hue. New research has shown that carotenoids not only act as building blocks for synthesising vitamin A but also have antioxidant properties.

However, although much is known about the structure of carotenoids, relatively little is known about how they are affected and absorbed by the human body. Knowledge on the bioavailability of carotenoids is of vital importance if advances are to be made towards utilising them to their full potential. Within Northernberries, four different varieties of sea buckthorn berries were assessed for carotenoid content, and the variety with the highest level was then used in an *in vitro* digestion procedure described in a previous report.

The total carotenoid contents of rowanberries were significantly higher (~30-55 µg/g fresh weight) that those generally reported. This could be a potential advantage to be pursued commercially. All four varieties studied in SCRI had the same types of carotenoids but the relative amounts varied. The carotenoids present were neoxanthin, violaxanthin, antheraxanthin, lutein, zeaxanthin, beta-carotene and the corresponding carotenoid esters (mainly beta carotene and zeaxanthin). All of these have reported beneficial biological activity.

Bioavailability studies, analogous to those performed for cloudberry, showed that the levels of carotenoids were reduced to about 50% of the original juice after gastric (stomach) digestion. This is a significant decrease in the levels of carotenoids present in the berry juice. The recovery rate of carotenoids in the colon-available samples was similar to that of the gastric, at around 50%, suggesting that any carotenoid that survives the gastric stage of digestion is unlikely to become damaged in the small intestine due to its alkaline pH and the stability of carotenoids at this pH range. As the hydrophobic carotenoids will be passively absorbed through the gut mucosa walls in the small intestine and enter the lymphatic system, gastric digestion is evidently the most damaging part of the digestive process for the bioavailability of carotenoids.

A timescale assay was carried out to assess the damage done by the gastric treatment on carotenoid levels. There was a substantial drop in the carotenoid content (25%) after 30 minutes of the gastric digestion but further incubation did little damage (30%). A repeat of this procedure was carried out and showed a large drop in percentage recovery within the first 30 minutes.

The same carotenoids were present in the OUT “colon available” sample as in the original, with the exception of the esters. The ester peaks have changed line shape, perhaps due to the partial breakage of ester bonds in the slightly alkaline conditions of pancreatic digestion or the activity of pancreatic lipases. There is little change in the ester peaks between the gastric and colon available traces, which confirms the theory that the most damage is done to the carotenoids in the gastric stage of digestion. Indeed, the esterified forms of carotenoids may prove to be a viable breeding target since their ability to survive acid digestion aids means that they are available for uptake. In addition, progression to the upper gastrointestinal tract is accompanied by a shift to alkaline pH, where the ester linkage is cleaved to yield the bioactive carotenoids which can then be absorbed more readily.

E8. Animal model shows the health potential of cloudberry (Mylnikov *et al.* 2005)

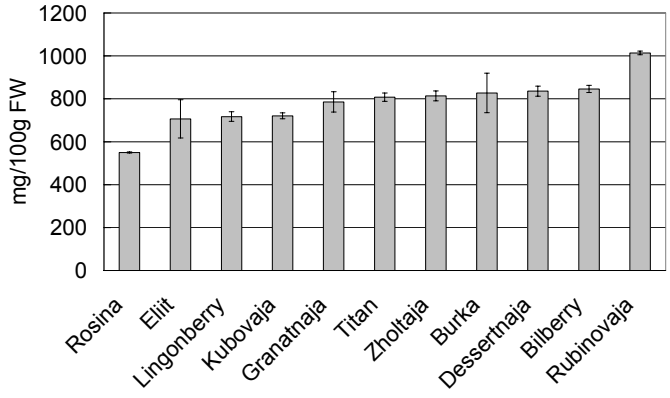
As stated above, the antioxidant capacity of red cloudberry (*Rubus chamaemorus*) juice correlates well with its phenolic content. The red berries have a markedly higher content of anthocyanins, particularly cyanidin and pelargonidin derivatives, than that found in the more common yellow cloudberry fruit. Conversely, the yellow juice has higher ellagitannin content. A feeding study was conducted to show the *in vivo* effects of the juices on lipid peroxidation in a sensitive *Drosophila melanogaster* stock. In young female flies there were significant ($P<0.01$) protective effects of cloudberry juice on both primary (hydroxyperoxide) and secondary (ketodiene) lipid peroxidation. In young male flies, significant ($P<0.05$) protective effects were found on primary products (hydroxyperoxides) with yellow juice and on secondary products (ketodienes) with red juice. With the red juice, a significant ($P<0.05$) decrease in ketodienes was found in both young and old males. This study demonstrated that the effects of berry antioxidants on lipid peroxidation were easily and rapidly tested *in vivo* with the sensitive *Drosophila* model. The results were published recently as a joint paper of SUP, SCRI and UKU partners (Mylnikov *et al.* 2005). The study would not have been possible without this excellent collaboration.

***Additional activity: Analysis of phenolic profiles and antioxidant capacities in sweet rowanberries* (Hukkanen *et al.,* 2005)**

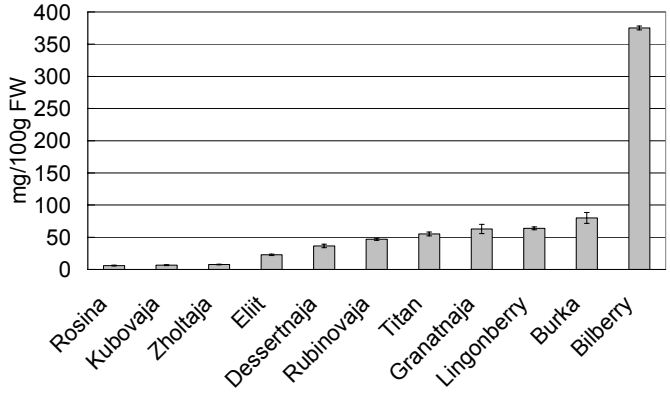
Further research was directed to sweet rowans after their exceptionally high phenolic content and antioxidant capacity were found in preliminary tests (see above). Sweet rowanberries were harvested in 2002-2004, and samples were analysed in 2003-2005. Nine cultivars were analysed: Burka, Dessertnaja, Eliit, Granatnaja, Kubovaja, Rosina, Rubinovaja, Titan and Zholtaja. Bilberry and lingonberry, which are known for their high phenolic and antioxidant contents, were used as reference materials. Total phenolic content, total anthocyanins, phenolic profiles (with HPLC) and antioxidant capacities (with FRAP and DPPH methods) were analysed. Values obtained for bilberry and lingonberry were consistent with those previously reported in the literature. Total phenolic content was high in all cultivars (Figure 9a) as it was in bilberry and lingonberry. The highest anthocyanin content was found in dark-red cultivars (Figure 9b), and only small amounts were found in orange cultivars. The levels were similar to those found in lingonberry. In bilberry, four times more anthocyanins were found than in the darkest rowanberries. Three anthocyanins were identified. Phenolic profiles were qualitatively similar in all cultivars, but quantitative differences were found. The main phenolic compound classes were anthocyanins, flavonols and hydroxycinnamic acids. Chlorogenic acid and neochlorogenic acid (hydroxycinnamic acids) were found to be characteristic for rowanberries, and the levels are near to those found in coffee beverages (Figure 9c). Their influence on health has not been studied yet but, for example, chlorogenic acid may prevent type 2 diabetes as indicated in recent studies. Antioxidant capacity was measured by two methods (FRAP and DPPH). Similar results were obtained with both methods (Figure 9d). Sweet rowanberries have as high antioxidant capacity as does bilberry.

The results suggest that sweet rowanberries have a great potential as a high-yielding and health-beneficial material for many types of uses. This will directly benefit the marketing of berries and increase the interest in their industrial use. The results have been presented in scientific meetings as a poster. The results were published electronically at the end of 2005 and the printed version should follow soon in the Journal of Agricultural and Food Chemistry. The findings of this study certainly merit further research related to health aspects and utilization of sweet rowanberries in various ways by the industry. There is also a great interest in the whole metabolite profiling of the berries to assess their overall content.

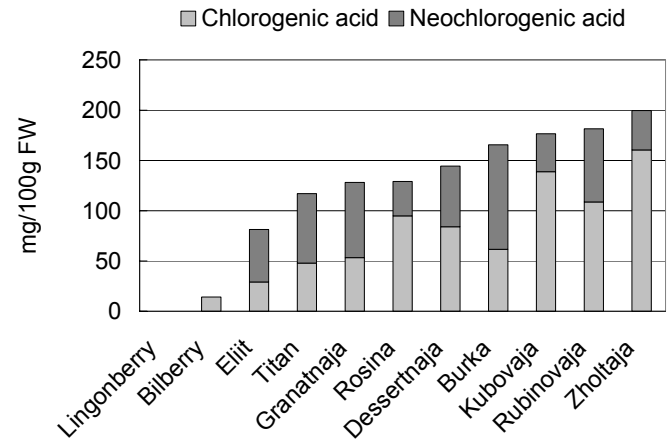
a)


mg/100g FW
1200
1000
800
600
400
200
0
Rosina
Eliit
Lingonberry
Kubovaja
Granatnaja
Titan
Zholtaja
Burka
Dessertnaja
Bilberry
Rubinovaja

b)


mg/100g FW
400
350
300
250
200
150
100
50
0
Rosina
Kubovaja
Zholtaja
Eliit
Dessertnaja
Rubinovaja
Titan
Granatnaja
Lingonberry
Burka
Bilberry

c)


Chlorogenic acid
Neochlorogenic acid
mg/100g FW
250
200
150
100
50
0
Lingonberry
Bilberry
Eliit
Titan
Granatnaja
Rosina
Dessertnaja
Burka
Kubovaja
Rubinovaja
Zholtaja

d)

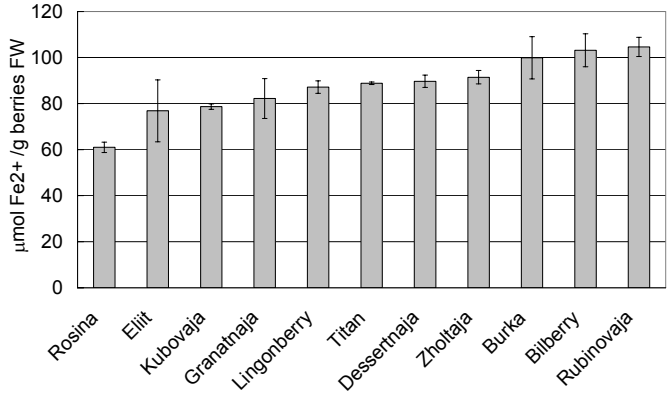

µmol Fe2+ /g berries FW
120
100
80
60
40
20
0
Rosina
Eliit
Kubovaja
Granatnaja
Lingonberry
Titan
Dessertnaja
Zholtaja
Burka
Bilberry
Rubinovaja

Figure 9. Total phenolic (a), total anthocyanin (b), and chlorogenic and neochlorogenic acid (c) content and antioxidant capacity measured with FRAP method (d) in sweet rowanberries, bilberry and lingonberry.

A11: Pollination and pollination effectiveness (HOLT)
E3. Pollinating insects improve cloudberry yield

Since pollination and thus weather conditions during cloudberry flowering time are critical for berry cropping, studies on pollinating insects were conducted in Norway. The experiments were taking place in the greenhouse and in the field (Figure 10). All experiments were repeated twice during two years. There were a number of problems in the field experiments. The plots had to be selected before the flowering took place and, therefore, it was difficult to find areas with a large proportion of female flowers (and enough male flowers). Strong winds during spring 2003 destroyed the tent that covered the plot. The experiment in the greenhouse complemented, however, the field experiments. In the greenhouse the number of female and male plants and also the number of bumble bees could be controlled. A problem in the greenhouse experiments was the difficulty in synchronizing the flowering of the female and male cloudberries with the maximum activity of the bumble bees in the hives. In spite of these problems, the studies showed that pollinating insects improve the yield of cloudberry. The results suggest that it is possible to increase the crop by putting hives in the field. This is especially important for obtaining crop on the revegetated peatland where no other vegetation and, therefore, no insects are present.

Figure 9. Pollination experiment in greenhouse at Holt

An effort was also made to collect bumble bees from the northern areas to produce hives with bees adapted to 24-hour day length. However, the bumble bees did not survive transport from Tromsø to Stavanger in the south where the company that produces the hives is located.

A12: Study of fruit development and development of seedless (parthenocarpic) fruits of cloudberry
E9. Knowledge of fruit development and flower induction of cloudberry (UiTo)

Plenty of new knowledge was obtained about the fruit and flower development of cloudberry during the project. Based on the flower induction studies, a guide of how to grow cloudberry in greenhouses with several production seasons within a year was prepared. The study of flower development at an early stage has also provided valuable information about the sex differentiation process, which again is important in order to develop a stable hermaphroditic clone. In addition, experiments showed that cloudberry develops parthenocarpic fruits when treated with 3 β-hydroxylated gibberellins. The experiments on fruit development also gave knowledge about the production of plant hormones needed for normal fruit development. An *in vitro* system was developed to study fruit development. The importance of these studies is above all the increased knowledge about the development of cloudberry fruit. This could be useful in the cultivation and breeding of cloudberry. In addition, the output of this activity, the seedless fruit, could be profitable on the market within a few years.

A13: Data analysis and writing (UKU, HOLT, SCRI, HÖN)
E10. Information about project outcomes transmitted through the wide network

Overall, the Northernberries project has produced so large amount of results that the data analysis and writing of the publications could not be finalised within the project period. The outcome from Norway will be three publications concerning fruit development. The last pollination experiment ended on summer 2005 and the statistics of this experiment is under way. This will be financed by Holt. Below is the list of scientific papers and other publications that the participants have published during the project from the Northernberries subject area. From other public presentations or activities, see "Dissemination and Transfer of Experience".

Publications

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Karjalainen, R. O., Hukkanen, A., Anttonen, M., Kokko, H., Kärenlampi, S. and Tiilikkala, K. 2002. Benzothiadiazole enhances phenolic compound production and resistance to powdery mildew in strawberry. Induced Resistance in Plants against Insects and Diseases, IOBC wprs Bulletin 25(6): 155-158.

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McDougall, G. J., Dobson, P., Smith, P., Blake, A. and Stewart, D. 2005. Assessing potential bioavailability of raspberry anthocyanins in an *in vitro* digestion system. Journal of Agricultural and Food Chemistry 53: 5896-5904.
McDougall, G. J., Shpiro, F., Dobson, P., Smith, P., Blake, A. and Stewart, D. 2005. Different polyphenolic components of soft fruits inhibit alpha-amylase and alpha-glucosidase. Journal of Agricultural and Food Chemistry 53: 2760-2766.
McDougall, G. J., Fyffe, S., Dobson, P. and Stewart, D. 2005. Anthocyanins from red wine – their stability under simulated gastrointestinal digestion. Phytochemistry, in press
Mylnikov, S. V., Kokko, H. I., Kärenlampi, S. O., Oparina, T. I., Davies, H. V. and Stewart, D. 2005. Rubus fruit juices affect lipid peroxidation in a *Drosophila melanogaster* model *in vivo*. J. Agric. Food Chem. 53: 7728-7733.
Nilsen, G., Martinussen, I., Ernstsen, A., Bhuvaneswari, T. V. and Junttila, O. 2002. Involvement of gibberellins during fruit development in cloudberry (*Rubus chamaemorus* L.). Acta. Hort. 585 (2): 517-520.
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7. Analysis of the results

The multidisciplinary nature of the project ensured that the project actually exceeded the expectations on many fronts. The combination of plant culture and agronomy skills (Kuopio and Holt) along with those on the phytochemical bioactivity both *in vitro* and *in vivo* (SCRI and SUP) ensured that all aspects of the fruit development as a commercial entity were covered. Since the planned Tacis funding for the Russian partner was not achieved, the lifespan study on *Drosophila* could not be accomplished.

The main objective was the advancement of cultivation and use of northern berries, particularly cloudberry. While it is clear that within such a short time it is not possible to reach the ultimate goal, the project was certainly taking a long leap towards it and has raised a lot of interest. A factor that should not be neglected is that this kind of project opens the eyes to

realise that the seemingly disadvantageous location of the Northern Periphery areas can be an advantage that can be exploited for the benefit of the area.

SWOT analysis

Strengths

The wide publicity of the project has served as a catalyst for many spin-off activities around these berries. A major strength in the project was the good professional skills of the key participants. It helped the project to obtain the aimed results and achieve the objectives set to the project.

The two main berries studied were cloudberry and arctic bramble. Nearest to the ultimate objective was that large-scale cultivation trials on cloudberry were conducted both in Finland and Norway. In this way farmers from the Northern Periphery region were directly involved in the development of good agricultural practices needed for the successful cultivation. Particularly in Norway the coverage of farmers was the whole Northern Periphery region, which ensured that outputs of the project are implemented in the whole region. This also gave the Northernberries project a wide publicity (see the number of newspaper articles: Chapter 10). The farmers and peat industry involved got opportunities to cultivate their peatland, and most of them will continue the business after the project ended.

The knowledge gained of cloudberry flowering and fruit development can be used in the future in the cultivation and breeding of cloudberry. In addition, the output of this activity, the seedless fruit, can be profitable on the market within a few years.

Studies on arctic bramble were also taken forward within this project. Based on the results obtained, a new project was planned and initiated, in which the downy mildew resistant clone together with new treatments supporting the protection against downy mildew can be taken to farm trials to find out the success and commercial viability of the tools developed during the Northernberries project. The method developed for the identification and quantification of downy mildew will help in monitoring the results.

All previous data on sweet rowanberries were combined to a publication (Hukkanen *et al.* 2005), in which the high antioxidant value of the unique varieties has been brought into spotlight. Northernberries project won a national food competition "Tolokun Välläys" with a proposal on the potential multiple uses of sweet rowanberries (juices) as food additive replacements (antioxidant, preservative) and nutrition ingredients.

The large number of analysis of bioactive compounds indicated that the berries do have a significant potential to be exploited for the health benefit of consumers both in the Northern Periphery area but also elsewhere. Completely new approaches were also taken to study the possible health benefits of the berries.

Weaknesses

Clearly the main weakness in this project was the limited time span available to fulfill the objectives and achieve the desired results. The duration was not sufficiently long for the cloudberry cultivations to grow dense and mature enough and the long-term productivity of the cultivations remained open. Thus, no cost-benefit analysis could be done on these initial cultivation studies. It is clear, however, that the cost of plantlets is presently high and starting the cultivation is rather expensive, needing relatively large amount of risk funding. Mass propagation of cloudberry in Norway was not achieved in the extent that was hoped for since the *in vitro* propagation of clones was more difficult than expected. It was not at all possible to screen all interesting breeding material within the project, contrary to the estimated follow-up of 2-3 plant generations. In fact, to get the first flowering plants takes 4 to 5 seasons.

It will take several more years to develop cloudberry into a commercially viable cultivated fruit crop capable of being delivered to local, national and international markets. The extension of the cloudberry penetration into an international arena is only now beginning, and could benefit from further support based on both the achievements made here with regard to cultivation, propagation and proof of the benefits to health.

Only one strong candidate for downy mildew resistant arctic bramble clones was found. Controlled *Peronospora* inoculations were not possible during this project. Experiments in the real cultivation conditions should be run at least for three years to get reliable results.

Opportunities

The wide contact surface to the enterprises has generated new business ideas which may in the future bring new products in the market, and thus new income to the Northern Periphery area. The increasing sophistication of methods and the awareness of the consumers means that there is a market for ‘novel’ or traditional but minimally commercialized fruits that have associated health benefits. Clearly the fruits subject to the research effort here fall into that category. In particular advances made with regard to the cultivation of cloudberry linked with the corresponding digestion, bioavailability and *in vivo* efficacy studies mean that this consolidated approach allows cloudberry per se to be taken forward and developed not only as a fresh fruit but as a healthy ingredient to be added to other processed products; fruit bars, yoghurts, juice blends etc. Moreover, once the production and supply chain has been established at the national level the global market can be approached.

Reuse and revegetation of the wide areas of cutaway peatlands is an important goal for the future and provides an opportunity for the large-scale cultivation of cloudberry. Preliminary results obtained in Kuusamo have been so encouraging that the entrepreneur plans to continue and extend the cultivation area. Also the farming trials and results in Norway have greatly increased the interest in cloudberry cultivation. New business can also be developed or the present business strengthened by the propagation of more plant material (cloudberry and other) for cultivation purposes.

Environmental and consumer friendly berry production may be achieved by using tested elicitors to protect arctic bramble from downy mildew. The compounds are non-toxic, a large-spectrum resistance is achieved, no tolerant pathogen strains are likely to develop, and no long withdrawal periods are needed. These compounds could be used in organic production as well as in conventional production together with other plant protection agents or fertilizers. This will not only benefit the growers and the environment, but also marketing of berries and berry products.

Threats

One threat to the outcomes generated here will be if global warming results in a significant shift in the annual temperature or increased seasonal fluctuations in temperature and rainfall. These problems cannot be accounted for in the limited time span of this project. However, attempts at cultivation the successful northern varieties in more southern latitudes (SCRI) have proved successful and the fruits do not appear to be significantly different from those normally found in e.g. Finland. This means that for weather conditions and environment at least, cloudberry appears to have the capacity to survive over a wide latitude range. One thing that was not tested was the susceptibility of the Finnish cloudberry to UK pest and pathogen resistance. To fully commercialize and broaden the uptake of cloudberry, or any native northern fruit, appropriate national pest and pathogen testing will need to be undertaken. Additionally, a change in the past and pathogen population may accompany global warming and needs to be born in mind during cultivation and development. Overall, there is a continuous war between plants and pathogens, and continuous efforts are thus needed to overcome the disease outbreaks.

Expenditure in relation to outcome and results

Since the partners were well experienced and skilled in their specific areas, not much time and money was wasted for unproductive learning.

In the project co-ordination, reports delivered two to three times a year took much more time than originally planned. Complexity of the project sheets and filling of different files was difficult in the beginning. It is estimated that coordination costs were more than doubled from the planned 108.000 EUR.

Cloudberry mass propagation (263.500 EUR), breeding and selection (120.000 EUR) together corresponded quite well to the actual costs. Sufficient number of plantlets was propagated to start the planned field studies. Also the propagation of the breeding material was successful; two cloudberry varieties have been selected, as originally planned, which are anticipated to have commercial potential. Also the downy mildew tolerant arctic bramble clone is ready for further cultivation trials.

Lower expenditures (planned 119.500 EUR) were allocated to the model cloudberry farm and training activities as well as product development. Regardless of that, two model farms were successfully established, i.e. one in Norway and one in Finland. It was decided not to train large groups of farmers before clear evidence is gained of successful cultivation and farming practices. The model farmers have expressed their willingness to share their practical know-how in the future with other interested persons. Product development was mainly conducted in companies using their own R&D funding.

The development of machinery for cloudberry planting reached the goal and it has been successfully used in the establishment of cultivations. The allocated money (65.000 EUR) was well in balance with the outcome. However, the company developing the machinery was changed in the beginning of the project to a less expensive one.

Cloudberry disease and monitoring activities were combined together with the selection of downy mildew tolerant arctic bramble (40.000 EUR). In practice, all activities were directed to *Peronospora* since no other significant diseases emerged. A sensitive molecular method was developed to diagnose the disease and it can be used in the future for better disease monitoring and selection of tolerant clones. This was a necessary step and the costs were in balance with the outcome.

Winter-hardiness of new berry plants and collection of berry samples can be seen, together with the studies on the basis of antioxidant capacity of northern soft fruits, as an entity. All berries studied in the project were subjected to analyses of bioactive compounds and to various bioassays. Total costs of these activities were 230.000 EUR. Slightly less funding was used to this part of the project since SCRI was not in the position to use all the money allocated to them. This part of the project produced many international publications which reach the wide international scientific society.

Pollination, flower and fruit development studies (90.000 EUR) done in Norway led to a practical guide on how cloudberry can be directed to flower three times within a season in greenhouse conditions. This will directly benefit the breeding and propagation efficiency of cloudberry. Pollination trials particularly in open field faced some problems. The induction of seedless fruits is seen as having commercial potential in the future. For this reason it is justified that the main efforts in this part of project were directed to more basic studies which will result in several scientific publications.

Data analysis and writing (130.000 EUR) has been a very important part of the project, and has resulted in many good quality publications. The production of the DVD video was done with minimal costs but is very informative and useful in demonstrating the various aspects of the project and the opportunities that berries can provide. We have not produced brochures or general information sheets since it was felt as an unnecessary cost considering that the subject was of high interest to the media which took good care of the visibility of the project.

8. Implementation and impact of the results

All the results obtained within this project will have impact in the future. The DVD video combines the main results of the project in an easily understandable, popular way. The material collected is equally usable in the partner organisations, local areas, regions and nations, as well as internationally. Speak is both in Finnish and in English to confirm the approachability to a wide audience. It is meant to inspire people of different backgrounds and interests to exploit the berries of north in multiple ways. Together with the wider international trends for healthier and tastier food and delicacies it can influence significantly in the berry business in all its forms in the coming years.

Cloudberry domestication

Cloudberry domestication has taken a clear step towards the commercial cultivation on peatlands. By improving the growth of natural cloudberry population by fertilization and watering, an increase of over 1000 kg per hectare has been achieved in the test plots. This experimenting in the model farm serves as an example of the significant improvements that can be achieved by good management practices.

The first hermaphroditic cloudberry variety in Finland, found from Pyhäntä, was named as "Cloudy". It can be expected that this variety has clear advantages in cloudberry cultivation and is preferred compared to the option of planting males (not producing berries) and females separately. A new unique clone with red berries was named "Ruby". No process has been initiated to release these cloudberries as registered cultivars since we considered that this would not bring any particular advantages. Cloudberry nursery production has started in Finland. The knowledge of in vitro and rhizome propagation has been transferred to Biotaimi Ltd. (nursery, SME partner in Finland). The first greenhouse growing experiments have been done in Muuruvesi, Finland. There will be a need for more plant material and, therefore, more propagators, especially in Norway and Finland when the cultivation of cloudberry expands. Flower induction studies in Norway resulted in a guide of how to grow cloudberry in greenhouses with several production seasons within a year.

Studies in Norway showed that pollinating insects improve the yield of cloudberry. This may generate business that produces hives for pollination purposes in cloudberry cultivations. A planting machine was developed and turned out to be well-suited, with adaptations, to different kinds of peatlands. The planting machine is very useful for revegetation of open peatland and for large-scale cloudberry cultivation. The machine is now at Holt and can be used by companies and farmers in the whole Northern Periphery region in Norway. The machine also serves as a prototype for new planting machines. The results have already initiated several R&D projects on wild berries in Norway. Project development (R&D projects) (Norway): ”Praktisk dyrking av molte” supported by Innovasjon Norge, start 2003 – still continue.

The original aim of the project was to decrease the production costs of cloudberry cultivation, to introduce cloudberry cultivation as a new business in the region and to create the network of R&D necessary for further business development on wild berries. This aim has been reached on growing, breeding and cultivation of cloudberry and the establishment of new commercial cloudberry fields in the region and a network of R&D and business along the value chain.

Solutions to downy mildew problem in arctic bramble

The test field evaluation of downy mildew resistant candidate clones has been performed and one clone has been selected for future cultivation trials. Based on different treatments of non-resistant arctic bramble varieties the best results were achieved with Bion® with or without potassium phosphate. Farm-Fos 44® showed promising results in field conditions. A sensitive method based on modern molecular biology (quantitative PCR) was successfully developed for the analysis of the presence and amount of downy mildew (*Peronospora sparsa*) in cloudberry and arctic bramble. Subsequent experiments with the resistant clone combined with selected treatments will be performed in 13 berry farms in a project that has recently received funding from the Employment and Economic Development Centre, North-Savo, Finland for two years (2006-2007).

New berry species for cultivation

All sweet rowanberry (*Sorbus* and hybrids) and saskatoon (*Amalanchier alnifolia*) varieties turned out to be winter-hardy. The nine sweet rowan cultivars (Burka, Dessertnaja, Eliit, Granatnaja, Kubovaja, Rosina, Rubinovaja, Titan, Zholtaja) are rich in potentially beneficial compounds for health, and they also have very high antioxidant capacity (Hukkanen *et al.* 2005). This will directly benefit the marketing of berries and increase the interest in their industrial use in coming years. The availability of the first berries has generated a wider interest in the berries apart from the Northernberries project. An example is a Master's thesis that has recently (2005) been finalised at the Faculty of Pharmacy in the University of Helsinki (Hanna Nuorviita) on the phenolic acids and antioxidants of sweet rowanberries. Berries have also been provided for other interested parties e.g. in UKU, Agrifood Finland and several companies. These can be expected to generate new products and business opportunities in the near future.

Health image of berries

The health image of berries of the north has been strengthened by the many studies conducted in the Northernberries project. In the future the consumers who are interested in taking care of their health will be increasingly interested in products made from the healthy berries of the north. This trend is connected to other changes in the society and the real impact is not directly predictable. This part of the project gained the most benefit from the international collaboration within the project.

Information about project outcomes transmitted through the wide network

The results have been presented during the project in a wide variety of platforms. Berries are clearly an interesting field and easily attract attention. The list of scientific papers and other publications that the participants have published during the project from the Northernberries subject area can be found under Chapter 6 (A13). From other public presentations or activities, see also "Dissemination and Transfer of Experience".

9. Transnationality

The co-operation was set up based on previous experience and collaboration between the key partners in Finland (UKU), Norway (HOLT), Scotland (SCRI) and Northwest Russia (SUP) during the previous Northern Periphery project "Northberry". The Swedish partner (HÖN) was incorporated into the team through contacts with the berry enterprise Polarica AB. Since HÖN and Polarica were in a process of starting a national program on bilberry cultivation, there were clearly common interests in exchanging the know-how. During the preparation of the project, NPP secretariat suggested contacts with a berry project funded by Highland Council. Collaboration was established with the leader of this project, Colin Sterling, and H N Products Ltd from Scotland.

A major added benefit for the project and the partners working transnationally was the information exchange channelled through the national coordinators. This consisted of information about other national projects and results, as well as about recent advances in the field in general through exchange of e-mails, articles etc. The project has also mediated information and contacts between berry traders, freezing units and processing enterprises. The exchange of knowledge between Finland and Norway has been most useful in the area of cloudberry cultivation. The collaboration between SCRI, Finland and Norway has provided plenty of new data about the composition of northern berries; this would not have been possible without the high expertise and expensive instrumentation available in SCRI. Since it was not possible to get Tacis funding for SUP, the main cooperation was done by finalising

the *Drosophila* studies and writing a publication. The input of SUP, UKU and SCRI was required for this.

One of the transnational difficulties was that SUP could not be incorporated as a full partner in the project and could not get own funding within the project. No other funding sources were found for SUP either. The participation of SUP was thus limited to meetings and short visits funded by UKU. The project would have clearly benefited from a more extensive partnership with SUP.

A Canadian group (regional authorities and peat industry and University representatives from Quebec area) interested in the same subject area visited UKU and HOLT to discuss further collaboration. Harri Kokko was invited to share the experiences obtained in Northernberries project in Labrador Straits Wildberry Conference in Canada. Based on these two independent contacts it would seem worthwhile to extend collaborative projects, with a common funding instrument, between wider northern areas, including the northern parts of USA, Canada and also Russia. All these areas have many common problems, and might thus also have many common solutions.

Another difficulty of the transnational nature of the project was not due to the partnership but to the way the financial arrangements and audition are done. The systems vary in different countries and the invoices may be written in a language which is not understandable to the overall auditor. Any ambiguities are very tedious to solve. We would suggest electronic invoices and centralised bookkeeping that could be controlled online.

The partnership developed during the project gives good grounds for the continuation of the transnational cooperation in one way or another. The ability to cooperate in an efficient way is largely dependent on the possibilities to get funding for joint projects.

10. Dissemination and Transfer of Experience

Berries are clearly an interesting field and attract attention easily. The results have been presented during the project in a wide variety of platforms.

The project web pages were held at (www.uku.fi/northernberries). In the official web pages of the Norwegian Crop Research Centre (http://www.planteforsk.no/) there are also several links to pages describing the task of the Norwegian partner in Northernberries. Through regular news about wild berries the public has obtained information about the project and about publications on wild berries.

The project meetings have been an important forum for exchange of knowledge and results transnationally. All partners have given presentations and views of the national work and partner activities. The publication activity has guaranteed the transparency of the results. National project meetings have been taken place annually in Norway. In addition all business partners have been visited several times by the Norwegian project leader. In Scotland, knowledge of northern berries and their cultivation in general has been transferred by the Highland Berry Growers Group. In Sweden, Polarica has distributed the information about Northernberries to the associate project.

Below is the list of occasions where information of the Northernberries project has been effectively distributed to a wider audience. In addition, some additional meetings of importance to the project are listed.

TV

28.08.02	Sweet rowanberries, *Harri Kokko,* ***MTV3,*** Finland, evening news
Jun 2003	Growing cloudberry in greenhouse, *Gerd Nilsen*, **NRK television**, Norway
23.06.03	Cloudberry is under development in Kuopio, *Harri Kokko* ***MTV3***, Finland news http://www.mtv3.fi/uutiset/kotimaa/kotimaa.shtml2003/06/174128
Sep 2003	Ut i Naturen, *Kåre Rapp*, **NRK**, Norway
20.12.04	Northernberries project and cloudberry breeding, *Harri Kokko*, ***TV1,*** Finland, morning news
12.09.05	Northernberries and publication of DVD-video, *Harri Kokko*, **Starvisio**, Finland

Radio

Jan 2003	Growing cloudberry in greenhouse, *Inger Martinussen,* **Radio Tromsø** (local radio, Norway)
19-21.08.03	”Verdt og vite” Radio, *Inger Martinussen* ***NRK P2***, Norwegian radio station (commercialization of cloudberry). http://www.nrk.no/programmer/radio/verdt_a_vite/2993311.htlm
Sep 2003	Norges glasset (research on cloudberry), *Inger Martinussen;* ***NRK P1*** Norwegian radio station
20.01.04	Radio interview, Harri Kokko and Hemmo Rossi (Lignell & Piispanen) **Oikea Asema**
16.09.05	Makeaa pihlajanmarjaa kotipihasta**,** *Harri Kokko****, YleKantti,*** *http://www.uku.fi/radio/ajankohtaisohjelmat/2005/09/20050916.shtml*

Newspaper

28.06.02 Modne multer om kun to uker, ***Finnmark Dagblad***
18.07.02 "Uttorvet myr i dyrkingsforsøk: Kan bli molteland", "Nye molteforsøk i Andøy","Andøy moletkommune nummer 1 " and "Et nytt steg innen moltekultivering",***Vesterålen***
01.10.02 Ny næring fra moltemyra, ***Nationen***
17.10.02 Forsinket molteprosjekt i Andøy, ***Vesterålen***
13.11.02 Dyrker molter i Andøy til våren, ***Vesterålen***
15-16.11.02 Molteforskninga i fare?, ***Norden***
01.02.03 Molteplukking i januar, ***Vest-Telemark Blad***
28.04.03 Viddas gull – ny næring, ***Finnmark Dagblad***
11.01.03 Fjellgull i januar, ***Tromsø***
15.01.03 Molter i stor skala, ***Nationen***
02.02.03 Old peat cut-away area for cloudberry cultivation, ***Koilismaan Uutise****t*
03.02.03 Marjoista terveyttä (Health from berries), ***Koilissanomat***
11.06.03 Kaldvær gir håp for bærene, ***Nordlys***
28.06.03 "Dyrker tusenvis av molter" peatindustry, ***Vesterålen***
03.07.03 Tror på godt molteår, ***Vesterålen***
04.07.03 Går bra med multa, ***Altaposten***
21.07.03 "Drops med søt smak av nature i Troms" Reisamat and Planteforsk Holt, ***Østlandsposten***
05.08.03 Gul, gylden og saftig, ***Troms Folkeblad***
05.08.03 Multe til alle, ***Østlendingen***
05.08.03 Molter til alle – men sky erfarne fjellfolk, ***Haugesund Avis***
05.08.03 Molter til alle – men sky erfarne fjellfolk, ***Varden***
05.08.03 Molter til alle – men sky erfarne fjellfolk, ***Sunnmørsposten***
05.08.03 Molte til alle – men sky erfarne fjellfolk, ***Sandefjords Blad***
05.08.03 Nok multer til alle, ***Drammens Tidende***
05.08.03 Molte til alle – men sky erfarne fjellfolk, ***Nationen***
06.08.03 Molteår med bær til alle, ***Dagen***
08.08.03 "Multefeber" and "Let i myrområder", ***VG***
07.08.03 Nok molter til alle, ***Klar Tal****e*
10.08.03 Skal masseprodusere multer, ***VG***
10.08.03 Klart for multeproduksjon, ***Aftenposten***
11.08.03 Molter – snart modne for dyrking, ***Varden***
11.08.03 Molter – modne for kommersiell suksess?, ***Troms Folkeblad***
12.08.03 Kan dyrke molter, ***Telen***
12.08.03 Multer modne for kommersiell suksess?, ***Sandefjords Blad***
20.08.03 Molteturen en saga blott, ***Trønder-Avisa***
03.09.03 Vil satse på molter, ***Telemarksavisa***
27.09.03 Moltedyrking ga mersmak, ***Rjukan Arbeiderblad***
30.09.03 Mye antioksidanter i bær – Norske bær beskytter best, ***Nationen***
15.11.03 "Tollere vokter koking av sirup" Reisamat, ***Nordlys***
xx.xx.04 "Gulle gode oppdrettsbær" Henry Hilmarsen cloudberry grower, ***Tromsø***
15.05.04 Molter med oppdragelse (planting machine for cloudberry), ***Finansavisen***
18.05.04 "Molter ny nisje" Fossli torv (peat industry and growers), ***Dagligvarehandelen***
04.06.04 Satser på moltedyrking (planting machine for cloudberry), ***Steinkjeravisa***
14.08.04 Viltvoksende medisin, ***Nordlys***
18.08.04 Alle tiders blåbærhelg, ***Nordlys***
24.08.04 Tomt for molter i fjellet, ***Oppland Arbeiderblad***
21.12.04 Lakanviljelystä toiveissa uusi elinkeino Satakuntaan, ***Satakunnan Kansa***
23.12.04 Yliopisto kehittää viljelykelpoista jättilakkaa, ***Savon Sanomat***
29.12.04 Lakan hyödyntäminen turvesoilla, ***Pyhäjokiseutu***
21.04.05 Interview of the berry Northernberries, ***Kuopion kaupunki***
30.04.05 Pensasmustikka on karun maan makea marja, ***Anjalankosken Sanomat***

23.06.05 Sweet rowan, newcomer for healthy consumption markets, ***University Kuopio Bulletin***

Jul 2005 Uudet marjakasvit tuovat vaihtelua, ***Koti, Kotitalouden ammatti- ja järjestölehti***

17.08.05 Bærre latskap – bær for syv milliarder råtner på rot, ***VG***

15.08.05 Bare eldre gidder å plukke, ***Fædrelandsvennen***

15.09.05 Hillan viljelystä saatu lupaavia tuloksia Kuusamossa, ***Koillismaan Uutiset***

19.09.05 Jalostustyön tulos: Pensasmustikat hurmasivat suomalaiset, ***Savon Sanomat***

19.09.05 Finner gull på myra – Ny arktisk merkevare, **Nationen**

28.09.05 Makeita sanoi tutkija pihlajanmarjoista, ***Kaupunkilehti Viikko Savo***

08.09.05 Pohjolan kultaa, ***Koillismaan Uutiset***

Seminars and presentations

31.01.03 Kokko H. Oral presentation ”Domestication of Northern Berries: 2002-2005” in Luonnonmarjojen tutkimus ja hyödyntäminen, Kuusamo, Finland (50 participants)

23.05.03 Kokko H. Valtakunnallinen puutarhapäivä (national garden day) in the Botanical Garden, UKU, Finland, Presentation ‘Northernberries project’ (30 participants)

12-13.08.03 Project group, meetings with Canadians peat and plant scientist in Kuopio (25 participants)

21.08.03 Kokko H. Presentation of plant biotechnology projects in the botanical garden to the rector and administration of the University of Kuopio

06.11.03 Kokko H. Oral presentation ”Domestication of Northern Berries” in Kuopio, Finland (20 berry farmers from Lappeenranta; MARAKASSI networking)

21.12.03 Kokko H. Seminars at the Institute of Applied Biotechnology in Kuopio (50 participants)

12.01.04 Kokko H and Kärenlampi S: Presentation of Northernberries project to IB high school students (~15 person)

02.-04.02.04 Kokko H. NPP leader partner seminar, Rovaniemi

23.03.04 Kokko H. Presentation of berry pojects to IB-high school students (14 participants)

03-08.05.04 Kokko H. Participation and poster in 8th International Symposium on Vaccinium Culture (Oreias/Portugal and Sevilla Spain)

14-15.05.04 Kokko H. Presentation of project “Domestication of Northernberries” during the National Puutarhapäivä in the Botanical Garden to exhibition audience (~50 person)

18.05.04 Kokko H. Presentation of berry projects to berry farmers and ProAgria personnel (15 participants)

06-11.06.04 Kokko H. Participation and oral presentation “Revegetation of peatland for cloudberry cultivation” 12th International Peat Congress “Wise use of Peatland” Tampere, Finland

16.09.04 Kokko H. Participation and presentation of Northernberries during to "Elintarviketyöpaja", TEKES (Technology Development Center), Kuopio, Finland (~20 participants)

09.10.04 Pölönen S. Oral presentation "Phenolics and antioxidants of sweet rowanberry cultivars during ripening of berries", Student seminar series, Kuopio (~40 participants)

08.10.04 Kokko H and Hukkanen A. Participation in the seminar "Terveysvaikutteiset elintarvikkeet" Kuopio, Finland

26-27.10.04 Kokko H. Presentation and training in plant pathology "Quantitative PCR of Peronospora sparsa in arctic bramble" (~15 participants)

30.09.05 Kokko H. Presentation "Cloudberry and project "Domestication of Northernberries”" during the Labrador Straits Wildberry Conference, Lanse Au Loup, Labrador, Canada (~50 person)

Meetings

Sep 2003	Negotiation with the Geological Survey of Finland in Kuopio. Project presentation (UKU) Inventory of Finnish peat area resource, monitoring of cloudberry vegetation and existing databases collected by GSF.
05.03.03	Meeting concerning co-operation between Oulanka Biological Station, University of Oulu, and UKU, Finland
01.04.03	Meeting concerning co-operation between MTT Ruukki and UKU, Finland
09.05.03	Meeting and planning with a berry farmer in Kuusamo, Finland
07.07.03	Kokko H. Meeting with rowanberry farmer Hannu Jaakkola in Kuopio
23-24.8.03	Meeting: Nordic berry cultivation and plant material exchange, Harri Kokko UKU, Colin Sterling Highland berry association, Karl and Ellinor Arne. In nursery, Mo Planteskole near Nordkjosbotn, Norway
25-26.8.03	Northernberries project meeting in Tromso, Norway
08.12.03	Meeting, commercialization of northern berries: Kokko, Kärenlampi and director Räsänen from Kalatukku Ltd. in Kuopio
16.01.04	Kokko H and Kärenlampi S: Meeting with Satu Pölönen, who is starting M.Sc studies on antioxidant capacity and phenolic profiles of rowanberries
08.03.04	Kokko H and Kärenlampi S: Meeting with Riitta Törrönen
09.03.04	Kokko H and Kärenlampi S: Meeting with Pertti Martikainen; planning of the peatland study (greenhouse gases)
18.06.04	Kokko H and Kärenlampi S: Meeting with Sergey Mylnikov in Kuopio
12.01.04	Kokko H, Niemi R and Nissinen M: planning of the expedition to Mitchurinsk, Russia
19.01.04	Kokko H, Koponen H and Marttila E: Meeting with Vapo Ltd concerning a new cloudberry cultivation trial
22-24.8.04	Northernberries project meeting, Kuopio, Finland
26.08.04	Kokko H. Presentation of the project “Domestication of Northernberries” to the Rector and administration of the University of Kuopio in the Botanical Garden (~15 participants)
22.9.04	Kokko H: Presentation of work in the Botanical Garden and Northernberries project to plant agrobiotechnology students, Kuopio, Finland (~30 participants)
03.10.04	Kokko H and Koponen H, Meeting and presentation of carbon balance measurements on peatland, TEKES, Kuopio
21.01.05	Planning of a new cloudberry and peat carbon balance project with Martikainen P, Koponen H from the Department of Environmental Sciences, University of Kuopio
01.02.05	Possibilities of bilberry and blueberry cultivation in China, Teknia Ltd (Ari Virtanen)
08.02.05	Planning of arctic bramble project: cultivation, breeding, export (Jorma Pylkkänen, Teknia)
23.02.05	Planning of DVD video (Kalle Toivonen, Jouni Valtonen)
01.03.05	Development of new greenhouse technology for cloudberry propagation and cultivation (Lakome Oy)
02.03.05	Meeting with the mentor of a new trainee (Katri Nevalainen) who will start work on micropropagation
07.03.05	Planning of the new arctic bramble project (ProAgria, Teknia)
09.03.05	Preparation of a brochure on arctic bramble together with Teknia (in Finnish)
08.04.05	Visitor from World Bank (Eija Pehu)
29.04.05	Planning of tests on antimicrobial properties of rowan berry juices (Atte von Wright, Paula Hyvönen, Marja-Leena Laitinen)
19.05.05	Meeting with arctic bramble growers, Teknia
19.06.05	Exchange of berry material for studies on anti-infective effects (Kaarina Tikkanen)
28.06.05	Exchange of berry material for studies (Puupponen-Pimiä, VTT)

Courses

09.06.02 A farmer group visited the berry test fields in the University of Kuopio

0x.09.02 Course in cultivation of cloudberry for private farmers in Snåsa. (Kåre Rapp) (Holt)

Other

0x.09.02 Testing of planting machine prototype at Fossli A/S, Stjørdal. (Kåre Rapp) (Holt)

23.10. 03 Scientific papers concerning healthy benefits of cranberry were delivered to Thomas Niemi, Polarica AB, Sweden

05.11. 03 Plant biotechnology interview for video, Sirpa Kärenlampi

14.6-28.9.03 Participated in an exhibition at Tromsø Museum "Kvaster på såret – remedy in green"

11-13.8. 04 Kokko H and Biotaimi Ltd. Horticulture expedition in Lepaa, Finland

16.09.05 "Om molter og merkevarer" forskning.no

19.09.05 "Molter kan bli gullbutikk", Bt.no http://www.bt.no/okonomi/neringsliv/article207125.ece

19.09.05 "Vil gjøre molte til merkevare", Nyskapning.no, http://www.nyskapning.no/cgi-bin/ukeavisen/imarker?id=109113

Posters

02-06.09.02 Martinussen, I., Nilsen, G., Ernstsen, A. and Junttila, O. 2002. Fruit development in cloudberry (Rubus chamaemorus L.). – Book of abstracts 341 (Poster 127). 13th Congress of the FESPP. Kalliopi A. Roubelakis - Angelakis (ed). Hersonissos, Heraklion, Crete, Greece

20.01.03 Stewart, D., Dobson, P., Deighton, N., Davies, H. V., Kokko, H. and Kärenlampi, S.: Antioxidants in Northern berries. Suomen kasvifenolitutkijoiden kolmas symposium, Kuopio, Finland, 20.1.2003. Poster in the 3rd Symposium of the Finnish Plant Phenol Researchers, January 20, 2003, University of Kuopio, Finland

05.-09.5.04 Hukkanen A: Participation and poster presentation: International Joint Workshop on PR-proteins and Induced Resistance, Helsingør, Denmark "Priming or SAR induction by BTH suppress powdery mildew on strawberry"

05-09.05.04 Hukkanen, A., Kokko, H., Buchala, A., Karjalainen, R. and Kärenlampi, S.: Priming or SAR induction by BTH suppress powdery mildew on strawberry. International Joint Workshop on PR-Proteins and Induced Resistance, May 5-9, 2004, Helsingør, Denmark, p. 73

06-11.6.04 Kokko, H., Teittinen, H. and Kärenlampi, S.: Revegetation of peatland for cloudberry cultivation. 12th International Peat Congress: Wise Use of Peatlands, June 6-11, 2004, Tampere, Finland

10-11.7.04 Kokko H, Hukkanen A, Pölönen S. and Kärenlampi S: Poster presentation "Sweet Rowanberry - a novel source of fruit phenolics" in the Symposium "Berries in Cancer prevention", Lahti, Finland

16-20.8.04 Hukkanen A, Martinussen I, Rothe G, Stewart D: Poster presentations during "XXII International Conference on Polyphenols", Helsinki, Finland

25.8.04 Kokko, H., Hukkanen, A., Pölönen, S. and Kärenlampi, S.: Sweet rowanberry varieties have high phenolic content and antioxidant capacity. XXII International Conference on Polyphenols, August 25-28, 2004, Helsinki, Finland, p. 245-246

11. Conclusions

Brief outline of the outcomes

The Northern Periphery projects Northberry and Northernberries have been extremely important in bringing forward new technologies, increasing awareness and highlighting new opportunities. The wide publicity and great attention to the natural, renewable treasures of north has been the greatest outcome of the project. The good image of berries has raised significant interest; many interviews have been given to newspapers, radio and TV in Finland, Norway and Scotland. There is clearly new thinking and increasing excitement about the new horizons.

Northernberries project has given great opportunity to strengthen the collaboration within the Northern Periphery region. In addition, the project has made use of the broad network built through the whole production chain from breeding to cultivation, processing and marketing of cloudberry. New methods were developed to plant propagation, cultivation, plant disease diagnostics as well as to the studies on health effects of berries. Clearly positive cultivation experiences were obtained for the first time for cloudberry in a wider scale, which encourage the farmers to continue their efforts. Besides cloudberry cultivation, arctic bramble cultivation is coming to a new start.

What actions are necessary to develop this topic in the future and what is the best way of achieving this?

Berries will remain an important field of research and development far to the future. The overall metabolite profile should be studied with the new profiling methods (e.g. metabolomics) to fully understand the composition of these berries. How safe, healthy and nutritious are they? Berries are good targets for the new nutrigenomics studies. Development of new products which retain and make best use of the health beneficial characteristics of berries will be important. Berries are potentially excellent sources of new functional foods. However, equally important is to make sure that the availability of the berries is sufficient and their quality is good. Therefore, the agricultural practices need to be developed further in parallel with the product development. Agriculture remains an important source of livelihood also in the Northern Periphery but specialization will be very important for its survival and attractiveness. New technologies such as biotechnology should be incorporated as powerful tools in this development.

The following administrative actions should be considered in the future development of the actions:
1. Reporting of the results and financing should not take too big part of the project resources. International auditing system should be reconsidered.
2. There should not be the same pre-set maximum funding for all projects.
3. Funding period should be longer whenever the outcome of the project clearly seems to benefit from it.
4. A common funding instrument should be developed for the Northern Periphery and other similar type of regions e.g. in Russia and North-America.