Project description

New methods for organic raspberry production in polyethylene tunnels

PART 1

1. Objectives

Principal objective: Profitable and high quality organic production of red raspberries in polyethylene tunnel

Sub goals:
1. Methods for control of important pests
2. Develop efficient systems for supply of organic nutrients
3. Develop methods for manipulation of climatic conditions (light and temperature) for early growth start and extending of the harvest season
4. Knowledge of the effect of climatic condition on berry quality related to health benefits.

2. Frontiers of knowledge and technology

Pictures from the left: Larva of raspberry beetle; enhanced raspberry beetle funnel trap developed at SCRI; exclusion fence of insect-net seen from outside; organic raspberries from 65º N.

Subgoal 1. Methods for control of important pests
Raspberry is attacked by a number of viruses, fungi, mites and insects (Ellis et al 1991, Gordon et al 1997, Trandem & Smith Eriksen 2003). One of the advantages of tunnel growing is the reduced occurrence of important fungal diseases like *Botrytis* rot. Unfortunately, the opposite is true for many pests, and the lack of economically viable pest control methods is one of the major bottlenecks for organic tunnel production of berries. Growers starting an organic production of red raspberries in Norway are allowed to use physical/mechanical measures and biological control. However, few of these measures have been tested specifically in tunnel raspberries, and there is little knowledge on how to use them in a way that works in this culture. Elsewhere in Europe, pesticides made from plant extracts, like azadirachtin and pyrethrum, are available in organic growing. No such products are currently registered in Norway, and there is a considerable scepticism about their use in organic growing. Growers starting an organic production of red raspberries must therefore do so without any documented control measures for pests like raspberry beetle (*Byturus tomentosus*, the most important direct insect pest) and raspberry aphids (*Aphis idaeus* and *Amphorophora idaei*, direct pests as well as virus vectors). This is a considerable risk in a high investment production like tunnel growing.

Based on the potential for getting results that can be implemented by growers in relatively few years, we will work with the following three methods in this project. One is species-specific for the most serious pest, while the two others are more general, aimed at larger and smaller arthropods, respectively:

1) Mass trapping of raspberry beetle: The larvae of this beetle typically damage 30-80% of the berries in unsprayed fields (Ekeland 2005), and these berries are not saleable. Eggs are laid in open flowers. One visual and two olfactory attractants for adult raspberry beetles of both sexes have been discovered by scientists at Scottish Crop Research Institute: White sticky traps mimicking raspberry flower colour are commercially available as a monitoring tool (e.g. Rebel Bianco®, Woodford et al 2000), while two attractive volatiles present in the flowers are being researched by SCRI and their commercial partners (Woodford et al 2003). One of the volatiles ('compound B') has recently been used in pilot studies of mass trapping in Scotland and Norway, as a potential tool for monitoring and control. Results from these studies show that a funnel trap enhanced with white panels and compound B can catch more than 100 beetles per day in the prebloom period (SC Gordon, ANE Birch, & N Trandem, unpubl data). This is 5-20x as many as Rebel sticky traps enhanced with the same compound, which did not catch enough beetles to affect the larval damage in Norwegian gardens with high *B. tomentosus* density (Ekeland 2005). Continued research is needed to find out how to exploit the enhanced funnel traps in a way that will decrease oviposition and the larval damage following. We believe the greatest chance of success is if trapping is started in first year of production to suppress populations below economic levels. If the beetle density is very high before trapping commences, the mass trapping may just act to release surviving beetles from competition for oviposition sites (i.e. open flowers), and may not reduce larval damage sufficiently.
2) Exclusion fence of insect-net around tunnels: This method has shown effect against cabbage root flies (*Delia* spp) in Canada and Europe (Vernon and Mackenzie 1998; Meadow 2005) and it is now tested whether it also can keep strawberry blossom weevils (*Anthonomus rubi*) out of strawberry fields in Norway (NFR Proj 173279/I10). We think that it has a potential for preventing beetles, moths, sawflies and other large to medium sized insects from entering tunnels. The fence must be erected in the spring of the first production year at the latest.
3) Spraying with vegetable oil: Small arthropods with a high oxygen requirement (e.g. aphid eggs just before eclosion) will die from asphyxia if covered with a film of vegetable oil solution. . In addition vegetable oils may contain oleic acid, which is harmful to cell membranes, and are emulgated by soft soaps, which also have insecticidal effects (Copping 2004). Due to heavy taxation of plant protection products (including non-toxic vegetable oil products), growers prefer to buy ordinary rape- or soyseed oil and mix their own spray of water, oil and soft soap. The only additional requirement in organic growing is that the oil must be 100% GMO free. There are several potential problems with using oil-soap mixtures in berry crops: A tendency of more malformed ("catfaced") berries was found when rapeseed oil was applied in strawberries during bloom (Sønsteby 2003) - suggesting that pollination was affected - and a slightly altered taste was found when a commercial rape oil product ('ProNatur') was used on greenhouse blackberries 4 days before harvest (Sørestad et al. 2003). Moreover, we do not know the optimal concentration or oil type to use in homemade sprays. Therefore, we currently recommend oil sprays before flowering only, in dosages lower than 2%, while the need would be to spray also later. An interesting side aspect of rapeseed oil is its ability to reduce powdery mildew infection, which is a potential problem in tunnel berries, if mixed with sodium bicarbonate (Sønsteby et al. 2005).

Subgoal 2. Systems of nutrient supply

Most of the systems for nutrient supply in organic farming start with basic fertilisation before planting and adding of animal or green manure during the growing season. In organic as well as in conventional raspberry production, plants are grown using woven plastic mulches because it is labour-saving: the mulch control weeds and excessive primocane emergence in the row (Heiberg 1996). However, the woven cover makes it difficult and labour-demanding to add solid manure to the plants. Recently, a production method using liquid organic fertiliser during the growing season was successfully developed in tomato production (Verheul, 2005). This method might be adapted to organic raspberry production. With fresh products, contamination from manure is a big threat, and there is a need for systems that can guarantee clean fruits from organic production. Contaminated imported, frozen raspberries killed 5 persons in Denmark last year.

Another problem in organic crop production is to adjust the availability of nutrients to the nutritional needs of the plants. The nutrient requirement of raspberries is high, and a raspberry plantation should last minimum 8-10 year. The Norwegian organic raspberry growers have problems with avoiding either surplus or deficiency of N, and to avoid deficiency of B, Zn and Cu (Heiberg unpublished).

Subgoal 3. Methods for manipulation of climatic condition in tunnels

The production of raspberries in polyethylene tunnels is expanding in Europe. The benefits of production in tunnels are many: better climatic condition, especially higher temperature, less problems with fungi diseases and reduction of wind and rain damage (Pitsioudes *et al.* 2002; Oliveira *et al.* 1996; Carew *et al.* 2000). Production in tunnels has made it possible to grow raspberries during winter in Southern Europe, and extend the harvest season in Northern Europe (Oliveira *et al.* 1996; Allen and Raffle 2000; Svensson 2006).

An important task in this project is to obtain knowledge about the possibilities for tunnel production of raspberries as far north as 68º N, further north than raspberry is grown commercially anywhere today. The mild winters and cool summers of the coast line of Norway might be suitable for tunnel production. Main growing area for raspberries in Norway is in the West, in the fjord district of Sogn og Fjordane (~ 61º N 6-8º E), where the climate has proved to be very suitable for raspberries, with high yield and fruit quality and little winter damage (Vangsnes-Figure 1). Going further north along the coastline the summer gets cooler, but the winter climate is similar to the main growing district. As far north as in Brønnøysund in Nordland (65º N) the high quality raspberry cultivar 'Glen Ample' is performing well in organic outdoor production (Bøthun and Heiberg 2004). However, rain and wind are annually damaging the fruits during harvesting, reducing the yield. In Troms, 68º N, (the mean temperature is measured in Bjarkøy which is 10 km north of Grytøy, where the grower is located), the mean temperature is 9.2 ºC in May-September, and the temperature sum during growing season is too low for commercial outdoor production of high quality cultivars as 'Glen Ample' But, as the mean temperature in tunnels in Western part of Norway is at least 2-3 ºC above the outdoor temperature in summer (Heiberg unpublished), tunnels may render raspberry production at Grytøy possible. The effects of temperature on growth of raspberries are well known, but there is less knowledge about the effect of light levels (Carew 2000; Carew 2003). The effects of the special light conditions on raspberries in the north of Norway are not known. More days with cloudy weather in north will decrease the temperature rise in the tunnels, on the other hand, longer days have the opposite effect.

. The polyethylene in the tunnels reduces the light intensity. According to Rohloff *et al.* (2004) polyethylene roof in rain covers decreased photosynthetic active radiation (PAR) by 21 % in overcast weather and 47 % in sunny weather at 63º N, but the rain cover had an insignificant effect on taste and aroma quality in strawberries.

In strawberries, covering of the crop with fleece (eg Agryl) during spring is used successfully in Norway to avoid frost during early spring and to advance the harvest. In raspberries, such a cover is useless outdoor, as it gets damaged by the wind (Heiberg unpublished), but used inside tunnels this could help growers to advance the growth in spring. Early forcing by fleece covers had no significant effect on strawberry fruit quality (Anttonnen *et al*. 2006). In Norway, the cultivar 'Glen Ample' is dominating the fresh fruit market of raspberries. The demand in the market is solely for this cultivar and it is the most profitable cultivar for the growers as well.

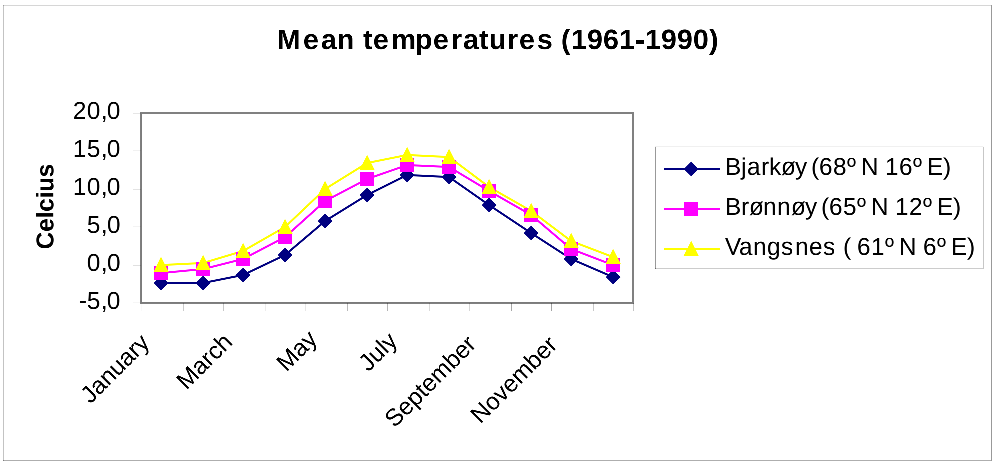

Figure 1. Meteorological data (mean temperatures 1961-90) for locations included in subgoal 3 (data from DNMI). Bjarkøy is located 10 km north of Grytøy, where one grower is located.

Subgoal 4. Effects on fruit quality

Consistent evidence indicates the importance of increased consumption of fruit and vegetables in improving human health (Block *et al.* 1992; Kris-Ethertorn *et al*. 2001). Raspberries contain high levels of potentially beneficial phytochemicals and antioxidants (Weber and Lui 2002; Deighton *et al.* 2002). The impact of temperature, light, fertilization and pests on these potential health beneficial components are not fully understood. There is a great annual variation in concentration of many compounds in raspberries (Burrows and Moore 2002). Temperature, light intensity and light quality are generally extremely influential in regulating the fruit and vegetable vitamin content (Lester 2006). In strawberry, the content of sugars and antioxidants was strongly influenced by the light levels. (Atkinson *et al.* 2006)

Generally, greenhouse grown plants will, due to combined effect of higher temperature and lower light intensity, have lower levels of most phytonutrients than plants grown outdoor (Lester 2006). However, individual compounds are differently affected. Atkinson *et al*. (2006) found that the use of highly reflective mulches increased the concentration of ellagic acid and ascorbic acid in strawberries, due to increased light intensity. The light intensity decreases with latitude, and the polyethylene roof might therefore affect the fruit quality more at northern than at southern latitude. On the other hand, the fruits will ripen earlier in tunnels, and long days might compensate for the lower light intensity.

3. Research tasks

Subgoal 1. Methods for control of important pests

<u>1) Mass trapping of raspberry beetle:</u> The main research task is to find out if and how it is possible to use the enhanced funnel traps in and around tunnels to decrease the amount of berries with larvae. The optimal density and placing of traps in different situations may vary (for example whether beetles are present or absent in the soil within the tunnel; whether the tunnel berries flower simultaneously or long before unprotected raspberries nearby, etc)

<u>2) Exclusion fence</u>: The research task is to document the effect of surrounding the tunnel with a 1.8-2.0 m high insect-net fence on the occurrence of pest insects in the tunnel plants.

<u>3) Vegetable oil sprays:</u> The research tasks will be to answer the following questions for tunnel raspberries, focusing on the main cultivar 'Glen Ample':

-What is the difference between soyseed and rapeseed oil in relevant physical properties?

-What is the effect of regular oil sprays on the control of aphids and other small arthropods?

-What is the range of target pests? (e.g., will this method kill newly hatched sawfly larvae?)

-What is the effect on pollination and berry quality when used during bloom?

-What is the effect on berry taste and quality when used after bloom?
-How high concentration can be used without phytotoxic effects?

Subgoal 2. Systems of nutrient supply
1. Find the right method/technique to supply organic nutrient solutions to raspberries plants grown while using woven plastic much.
2. Evaluate effects of different available liquid nutrient solutions on raspberry production

Subgoal 3. Methods for manipulation of climatic condition
As the light intensity is decreasing northwards, and the tunnels also decrease light levels, methods of manipulating the light levels in combination with methods to keep as high temperature as possible has got priority. The project will include covering of plants in early spring to obtain an early growth and protect against frost, and adding reflective ground cover during fruit ripening and flower initiation to obtain benefits from increased light levels in critical phases for fruit quality and productivity. Black woven mulch is the obvious choice for the north district, but further south, white mulch will be tested. White mulch is not heating the soil and might extend the harvest season. In strawberries white mulch affected the fruit quality (Anttonen *et al*.2006)

Subgoal 4. Effects on fruit quality
The project will study the effects of treatments in subgoal 3, and analyze for potentially beneficial phytochemicals and antioxidants.

Research approach, methods.

Subgoal 1. Methods for control of important pests
1) Mass trapping of raspberry beetle: Beetle catch, plant phenology and larval damage in tunnels with different spatial placing of traps will be compared (one arrangement per tunnel per year, 5-6 tunnels participating each year). In the last year (2006) of the Norwegian pilot project on trap design, we do trials with placing the enhanced funnel traps along the perimeter of open field organic raspberries (10 fields). The results will help us decide about spatial arrangements to be tried in the tunnel project. Most of the growers participating in the proposed project have/will have new fields, and that is an advantage. Early implementation of trapping, in order to avoid raspberry beetle population to build up to uncontrollable levels, is probably important for the mass trapping to work.
2) Exclusion fence: The occurrence of pest insects in at least three tunnels (=3 growers) surrounded by a fence will be compared with that of tunnels without a fence. The study will last for at least 3 years in each tunnel, and will start when fields are new. At the moment one grower has put up such a fence, the rest must be erected in 2007. The raspberry beetle traps at these growers will be placed outside the fence, close to nearby sources of raspberry beetle (wild and cultivated raspberry), to help keeping the beetles away from the tunnels.
3) Vegetable oil sprays: A literature study on different vegetable oils and products must be carried out first, to find the type of vegetable oil most suitable. Spray trials with different oil concentrations (in the range of 0.5-3 %?) at different phenological stages will then be performed to study phytotoxicity. In the last two years of the project, trials with different spray intervals (min 7, max 21, days?) will be done in at least 3 tunnels per year, monitoring the population of relevant pests and the berry quality.

Subgoal 2. Systems of nutrient supply
Different types of drips and nozzles and irrigation systems will be tested in small scale. The most promising systems will be applied on practical scale in commercial tunnels. Using these systems, different types of liquid nutrient solutions will be tested in combination with basic fertiliser given at the start of the experiments. Nutrient content and timing of supply of liquid nutrient solution will be

planned according to the nutritional needs of the plants. Soil and leaf samples will be taken and irrigation and yield will be registered to evaluate the efficiency of nutrient supply.

Subgoal 3. Methods for manipulation of environmental condition
Growers located at 3 different places along the coast of Norway (located at 61°, 65° and 68° N) will carry out experiments in their tunnels. All growers have the cultivar 'Glen Ample'.

The growers will include experiments with different types of covers (fleece and polyethylene) in combination with reflective ground cover on small plots (6-8 m length, replicated 4 times at each location). In the northern counties, Nordland and Troms, the growers will only use black plastic mulch in their tunnels, but in Sogn og Fjordane the experiment will also include big plots (tunnels of 1500 m^2), of either white and black plastic mulch, replicated twice. Photosynthetic active radiation (PAR), temperature (ºC), and relative humidity (RH in %) will be recorded at plant levels in the different treatments, and registration of plant growth, yield components (number of laterals, fruits per lateral) and fruit size will be carried out. Measurement of PAR to compare different treatments will be carried by hand held equipment. The measurements will include readings from different positions and weather conditions. For measurement of seasonal variation, one multi-sensor datalogger will be used.

Subgoal 4. Effects on fruit quality
Samples of fruits from each treatment in subgoal 3 will be collected 3 times during harvest period, and analysed for chemical components important for taste (soluble solids, titratable acids) and for potential health benefit components; total phenols, antioxidants (FRAP), anthocyanins, ellagic acid and ascorbic acid. Samples of fruit from outdoor production from the same farmers will also be sampled and analysed. Altogether there will be about 160 samples each year. The antioxidant activity will be analysed using the Ferric Reducing Ability of Plasma (FRAP) assay by Benzie and Strain (1996, 1999). The method depends on the absorbance change that appears when the Fe3+-TPTZ complex is reduced to the Fe2+-TPTZ form in the presence of antioxidants. The total phenols can be determined using the Folin-Ciocalteu method (Singleton et al. 1999). Anthocyanins display reversibly different absorbance spectra dependent on the pH environment. An absorbance maximum exists at 520 nm for the coloured form and the difference in absorbance at this wavelenght is proportional to the amount of anthocyanins present. Total monomeric anthocyanins (TMA) will be determined using the pH- differential method (Gusti and Wrolstad 2001). Ellagic acid will be analysed according to the methods of Atkinson (2006).

4. Project organisation and management

The project will be headed by Dr Nina Heiberg, Bioforsk Njøs. Bioforsk Njøs is situated in Western Norway, in the main growing district for raspberries. Heiberg has long experience with developing raspberry production systems. At least 7 growers will participate in the project. That include the majority of current tunnel area for raspberries in Norway.

Sub goal 1. (Pest control). Dr Nina Trandem, Plant Health and Plant Protection Division, Bioforsk, is responsible. She has worked with IPM in berry crops since 1999. The pest control experiments will take place in commercial tunnels in cooperation with growers and local advisors (and SCRI, see below). The Division currently has several projects on alternatives to pesticides in various cultures, including exclusion fences.
Sub goal 2. Testing of drips and nozzles and irrigation systems in small scale will be carried out at Bioforsk Særheim and managed by Michel Verheul. Nina Heiberg, Bioforsk Njøs, will manage experiments in the commercial tunnels, in cooperation with Michel Verheul and the growers.
Sub goal 3. (Methods for manipulation of environmental condition) The experiments will be carried out in commercial tunnels and managed by Nina Heiberg at Bioforsk Njøs, in cooperation with the growers.

Sub goal 4. (Effect on fruit quality). Norwegian University of Life Sciences by Dr Anne-Berit Wold is responsible for the analyses of antioxidants and phytochemical compounds. The analyses for soluble solids and titratable acids will be carried out at Bioforsk Njøs (responsible: Nina Heiberg). The budget include engagement of local advisors (LFR) to some of the registration work at farms.

5. International co-operation

Pest control**:** Since 2002, Bioforsk (formerly Norwegian Crop Research Institute) has cooperated with Dr Nick Birch and Dr Stuart C Gordon at Scottish Crop Research Institute (SCRI) and their partner Agrisense Ltd (trap and dispenser manufacturer), in testing various lure-enhanced trap designs for raspberry beetle. SCRI currently has 5 years funding (as part of a Defra Hortlink project, 2006-2011, Ref HL0175) to study raspberry beetle trapping and other methods within IPM of protected raspberries, and they would like to continue the cooperation with Bioforsk on the raspberry beetle traps. SCRI is the leading research institute on Rubus in Europe.
Nutrient supply: At The Danish Institute of Agricultural Sciences (DIAS) a new project regarding organic growing of raspberries in containers under rain cover is starting in 2007. A common goal is to test different organic nutrients suitable for raspberries, and we will cooperate in this task (Holger Daugaard, personal communication).

6. Progress plan - milestones

	2007				2008				2009				2010			
Raspberry beetle: mass trapping trials		x	x			x	x			x	x			x	x	
Exclusion fence trials		x	x			x	x			x	x			x	x	
Literature survey, vegetable oils	x															
Phytotox & efficacy trials, vegetable oil		x	x			x	x			x	x			x	x	
Testing nutrient supply systems, small scale	x	x	x			x	x									
Testing nutrient supply systems in tunnels			x	x		x	x			x	x					
Exp. with organic nutrient supply						x	x	x		x	x	x		x	x	x
Evaluation of organic nutrient supply								x				x				x
Exp. including mulch and cover,		x	x			x	x			x	x			x	x	
Analyses of chemical compounds,				x	x		x	x			x	x			x	
Publication/dissemination of results										x	x	x	x	x	x	x

7. Costs incurred by each research performing partner

Executive partner	Personal/ indirect costs	Equipment	Other	Total
Bioforsk	1935	250	560	2955
UMB	200	600		800
LFR (local advisors)	400			400
Total				*4155*

8. Financial contribution by partner

	2007	**2008**	**2009**	**2010**
Collective user funding applied for, Avtalemidler/Fondet	504	388	388	382
Applied for NFR (The Research Council	756	582	573	
Total	1260	970	970	955

Literature cited

Allen J.& Raffle S. 2000. Raspberries under cover. Grower 3.feb. 2000:12-14.

Anttonen M.J., Hoppula K.I, Nestby R., Verheul M.J. & Karjalainen R.O. 2006. Influence of fertilization, mulch color, early forcing, fruit order, planting date, shading, growing environment and genotype on the content of selected phenolics in strawberry (*Fragaria x ananassa* Duch.) fruits. J. Agric. Food. Chem 54: 2614-2620.

Atkinson C.J., Dodds P.A.A., Ford Y.Y., Le Miére J., Taylor J.M., Blake P.S. &Paul N. 2006. Effects of cultivars, fruit number and reflected photosynthetically active radiation on *Fragaria x ananassa* productivity and fruit ellagic acid and ascorbic acid consentration. Annals of Botany 97:429-441.

Benzie I.F.F. & Strain J.J. 1999. Ferric reducing antioxidant power assay: Direct measure of total antioxidant activity of biological fluids and modified version of simultaneous measurement of total antioxidant power and ascorbic acid concentration. Methods in Enzymology, 299, 15-27.

Benzie I.F.F., & Strain J.J. 1996. The ferric reducing ability of plasma (FRAP) as a measure of “antioxidant power”: the FRAP assay. Analytical Biochemistry, 293, 70-76.

Block G., Patterson B. & Subar A. 1992. Fruit, vegetables and cancer prevention: a review of the epidemiological evidence. Nutrition and Cancer 18:1-29.

Bøthun M. & Heiberg N. 2004. Satsing på økologisk bringebær (Production of organic raspberries in Norway) Norsk Frukt og bær 7(4):16-18.

Burrows C. & Moore P.R. 2002. Genotype x environment effects on raspberry fruit quality. Acta Hort. 585:467-473.

Carew J.G., Gillespie T., White J., Wainwright H., Brennan R. & Battey N. 2000. Techniques for manipulation of the annual growth cycle in raspberries. Journal of Horticultural Science and Biotechnology 75 (5):504-509.

Carew J.G., Mahmood K., Darby J., Hadley P. & Battey N.H. 2003. The effect of temperature, photosynthetic photon flux density, and photoperiod on the vegetative growth and flowering of ‘Autumn Bliss’ raspberry. J.Amer. Soc. Hort. Sci. 128(3):291-296.

Copping L.G. (ed.) 2004.. The Manual of Biocontrol Agents. Second edition, BCPC. 702 pp.

Deighton N., Stewart D. & Davies H.V. 2002. Soft fruit as sources of dietary antioxydants. Acta Hort.585: 459-465.

Ekeland M. 2005. Sticky traps enhanced with a plant volatile from raspberries (*Rubus idaeus*) as an alternative control method for raspberry beetle (*Byturus tomentosus*). (In Norwegian.) MSc thesis, Norwegian University of Life Sciences, 115 pp.

Ellis M.A., Converse R.H., Williams R.N. & Williamson B. (eds). 1991. Compendium of raspberry and blackberry diseases and insects. APS Press, 100 pp.

Gordon, S.C., Woodford, J.A.T. & Birch A.N.E. 1997. Arthropod pests of Rubus in Europe: Pest status, current and future control strategies. J. Horticult. Sci. 72 (6): 831-862

Gusti M.M. & Wrolstad R.E. 2001. Characterization nad measurement of anthocyanins by UV-visible spectroscpoy. In Current protocols in food Analytical Chemistry John Wiley & Sons, Inc., F1.2.3-F.1.2.13.

Heiberg N. 1996. Effekter av jorddekking med svart plast i bringebær (Effects of black plastic mulching in red raspberry). Norsk landbruksforsking 10(1):15-23.

Kris-Etherton P.M., Hecker K.D., Bonanome A., Coval S.M., Binkoski A.E., Hipert K.F. *et al*. 2002. Bioactive compounds in foods; their role in the prevention of cardiovascular disease and cancer. Amerian Journal of Medicine 113:71S-88S.

Lester G.E. 2006. Environmental regulation of Human health nutrients (ascorbic acid, ß-carotene, and folic acid) in fruits and vegetables. Hortscience 41(1):59-64.

Meadow R. 2005. Cabbage pests – what do we do without OPs? (In Norwegian.) Grønn Kunnskap 8 (2): 242-249.

Oliveira, P. B., Oliveira, C.M., Lopez-Da–Fonseca L. & Monteiro, A.A. (1996). Off-season production of primocane fruiting red raspberry using summer pruning and polyethylene tunnels. HortScience, 33: 31-5.

Pitsioudes A, Latet, G. & Meesters P. 2002. Out of season production of raspberries. Acta Hort. 585:555-558.

Rohloff J., Nestby R., Folkestad J.A. & Iversen T.H. 2004. Influence of rain cover cultivation on taste and aroma quality of strawberries (*Fragaria x ananassa* Duch.). Food, Agriculture & Environment 2(2): 74-82.

Singleton V.L., Orthofer R. & Lamuela-Raventos R.M. 1999. Analyses of total phenols and other oxidation substrates and antioxidans by means of Folin-Ciocalteu reagent. Methods in Enzymology, 299, 152-178.

Sønsteby A., Stensvand A., Skaug J., Hjeljord L. & Tronsmo A. 2003. Alternative methods against leaf powdery mildew and grey mould in organic strawberry production (In Norwegian with English summary and legends.) Grønn Kunnskap 7(2): 364-375.

Sønsteby A., Sween R. & Stensvand A. 2005. Alternative methods against leaf powdery mildew and leaf spot in strawberry (In Norwegian) Grønn Kunnskap 9 (2): 611-617.

Sørestad M., Smith Eriksen A., Trandem N. & Stensvand A. 2003. Plant protection plan for greenhouse blackberries (in Norwegian, online publication at www.bioforsk.no, select English and All publications to search)

Svensson B. 2006. Hallon ska odlas i tunnlar!. Viola (111) 10:24-25.

Trandem N. & Smith Eriksen A. 2003. Pest arthropods in greenhouse Rubus - diagnosis, biology and potential control measures (in Norwegian, online publication at www.bioforsk.no, select English and All publications to search)

Vernon R.S., MacKenzie J.R. 1998. The effect of exclusion fences on the colonization of rutabagas by cabbage flies (Diptera: Anhomyiidae). The Canadian Entomologist 130: 153-162.

Weber C. & Lui R.H. 2002. Antioxydant capacity and antioxydant properties of red raspberry. Acta Hort. 585: 451-455.

Woodford J.A.T., Birch A.N.E, Gordon S.C., Griffiths D.W., McNicol J.W. & Robertson G.W. 2003. Controlling raspberry beetle without insecticides. IOBC/wprs Bulletin 26 (2): 87-92.

Woodford J.A.T., Gordon S.C., Höhn K., Schmid K., Tuovinen T. & Lindqvist I. 2000. Monitoring raspberry weevil (*Byturus tomentosus*) with white sticky traps: the experience from three geographically distinct European areas. BCPC Conference –Pest & Diseases Vol 1:321-326

Part 2: Exploitation of results

10. Relevance for knowledge building areas

The most relevant knowledge-building area is Bioproduction, where one of the priorities is to ensure that Norwegian bioproduction becomes more robust by adapting to new market conditions and to increase the value of the production. One market trend in Norway as well as internationally is a demand for healthy, high quality products. The consumption of fresh raspberries in Norway has doubled every year since 2000, and will pass 400 tons in 2006. At the same time there is an increasing demand by consumers for products without pesticide residues, and the market for organic products is increasing. The production of organic raspberries is small, due to high production risks. The most important contribution of this project is to create knowledge that decreases these risks and thereby making Norwegian farmers able to increase the organic production of a high value crop, beneficial for public health, and to extend the growing area further north. Although the crop is small today, the value creation potential for the crop is big.

Most of the Norwegian R & D participants in this project are relatively young, and Bioforsk is not giving priority of Doctoral fellowship on this topic. At The University of Life Sciences, the project will include 1-2 Master students regarding methods and analyses of health beneficial components in fruit and berry crops.

11. Importance for Norwegian industry.

An important task in this project is to obtain knowledge about organic tunnel production of raspberries, further north than the crop is grown commercially today. With the oil industry and the expanding economy in the north of Norway, the demand for fresh fruits will increase. With a delicate fruit as raspberry, local production and short transportation is a big competitive advantage in the market. If successful, this project will develop methods for a new crop for the Nordland and Troms, with a high potential for value creation. In conventional production in West Norway, the value of a 0.1 ha raspberry crop is 50 000-70 000 NOK.

The project focuses on solving problems that obstruct organic growers to produce stable crops of high quality, which is turn is needed for building up the market for the product. The growers need methods for controlling the most damaging pests, and methods for secure and efficient supply of organic nutrients in tunnels. The profitability of tunnel production is dependent of the ability of harvesting the fruits when the prices are high and the growers also need more knowledge about climatic manipulations in tunnels, and strategies for extending the season. For growers in the northern part of Norway (Nordland and Troms) it is important to get methods for utilizing the long spring for early growth start, and at the same time protect the plants against frost.

An increasing volume of soft fruits for fresh market is produced in tunnels and this project will create knowledge of importance also for other growers, as is testified by several conventional growers joining the project. Conventional growers currently have only one pesticide (pirimicarb, an aphidicide) registered for use before harvest, and thus have no pesticides to deal with raspberry beetle, mites or other pests. The methods researched in this project will thus have a potential for use in conventional as well as organic production. Both growers and retailers will benefit from an increased production in tunnels, as tunnels extend the harvest season and the growing area. More knowledge about environmental impact on fruit quality, especially regarding the potential health beneficial components is important for the future marketing of the crop.

12. Relevance for Innovation programmes

The project is relevant for the following areas/priorities:

The Food program (Norwegian Research Council):

- Develop production of competitive, high value food product,
- Promoting health, food safety, ethics, sustainability and food quality

Fonds- og avtalemidler: Utilizing of natural conditions,

- Value creation of food production,
- Make food production more efficient
- Sustainable production of healthy food

13. Environmental impact

If successful, the project will increase organic growing of raspberries, and reduce the need for pesticides for conventional growers as well, which will be of great benefit for environment and health of growers and consumers.

14. Information and dissemination of results.

The users will be informed about the results through meetings and field excursions and through publications in “Norsk frukt og bær” (the magazine for Norwegian fruit growers). Results will also be published on the webpages of Bioforsk.
Internationally, the results will be published in refereed journals and on relevant Cost- and IOBC Workshops, ISHS symposium and other scientific meetings.