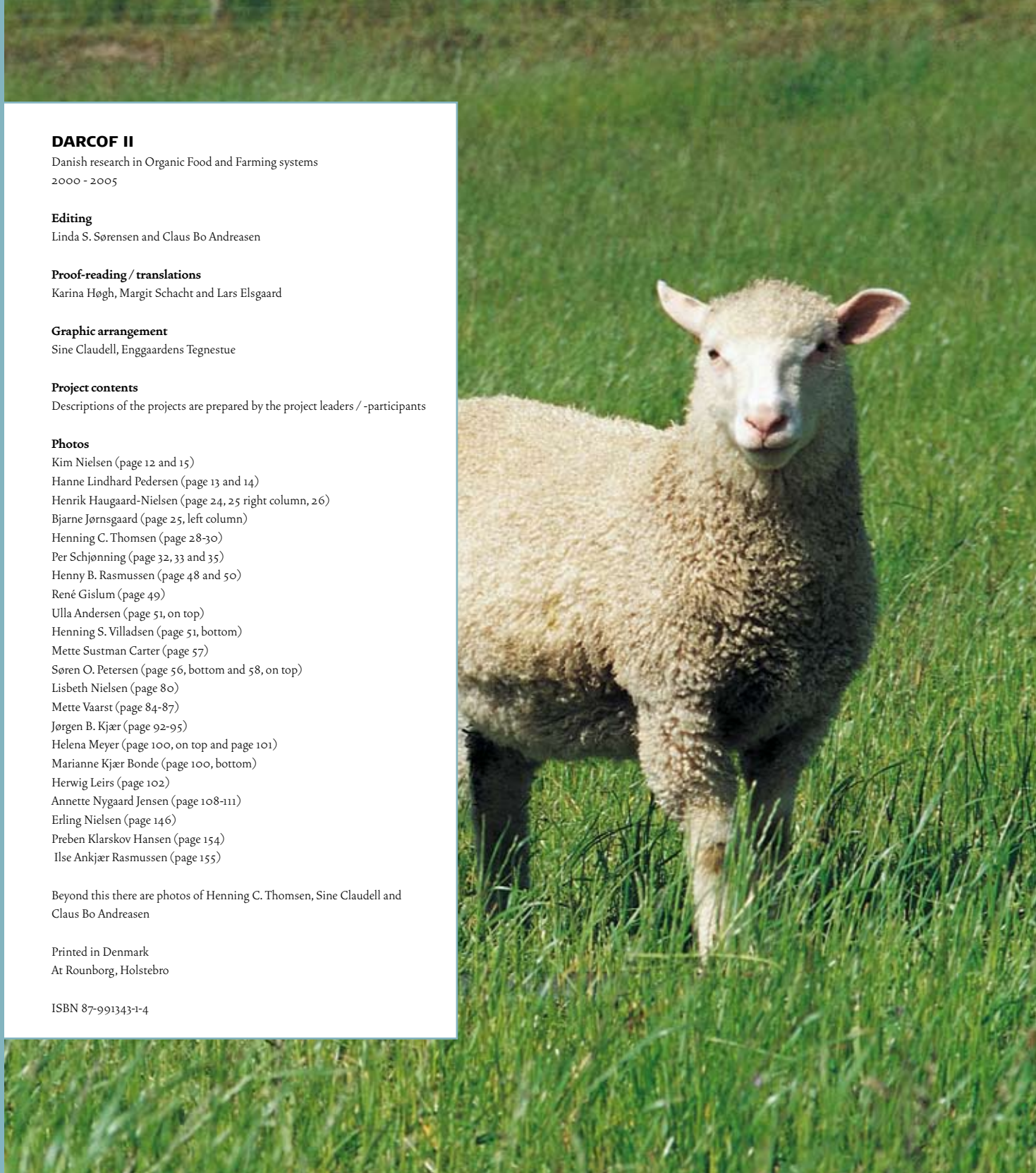
DARCOF II

Danish research in
Organic Food and Farming systems
2000 - 2005

Danish Research Centre for Organic Food and Farming



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Danish research in Organic Food and Farming systems
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Since the mid 1990s, the Danish Research Centre for Organic Farming (DARCOF) has initiated and coordinated research for the development of organic farming and food production.

DARCOF is a so-called "centre without walls" where the activities are based on collaboration between scientists and research institutes and organisations, business enterprises and authorities within organic food and farming. Scientists from approximately 20 Danish research institutes participate in the work. DARCOF is furthermore part of a comprehensive European network in the area.

From 1996 to 2000, DARCOF implemented the first coordinated research programme in organic farming. The research showed that organic farming has considerable potential in terms of environmental protection and landscape values, improved animal health and welfare and in connection with the effort to improve food quality.

On this background, a new research programme, DARCOF II, was initiated for the period 2000-2005. In this programme, a total of 41 research projects were carried out within the very diverse area of organic farming and food production.

Research in DARCOF II has produced a considerable amount of data that can be used in the development of the production on individual farms or food companies. Other results show how organic farming can be used for the public good, such as clean drinking water, a reduction in greenhouse gas emissions and healthier foods. The research also provides new perspectives in terms of promoting a more sustainable development in general agriculture.

It is important that the potential of research is fully exploited and that all have equal access to the results. The aim of this book is therefore to give a comprehensive and easily accessible overview of the projects in DARCOF II, of their objectives and of the main results achieved through the research.

If you would like further information about the research, please visit www.darcof.dk. This gives you direct access to the 1145 reports and articles that have so far been published as a result of the DARCOF II projects.

Enjoy your reading!

April 2006

Thomas Harttung, Chairman of the Board
Henrik Refsgaard, Chairman of the DARCOF User Committee

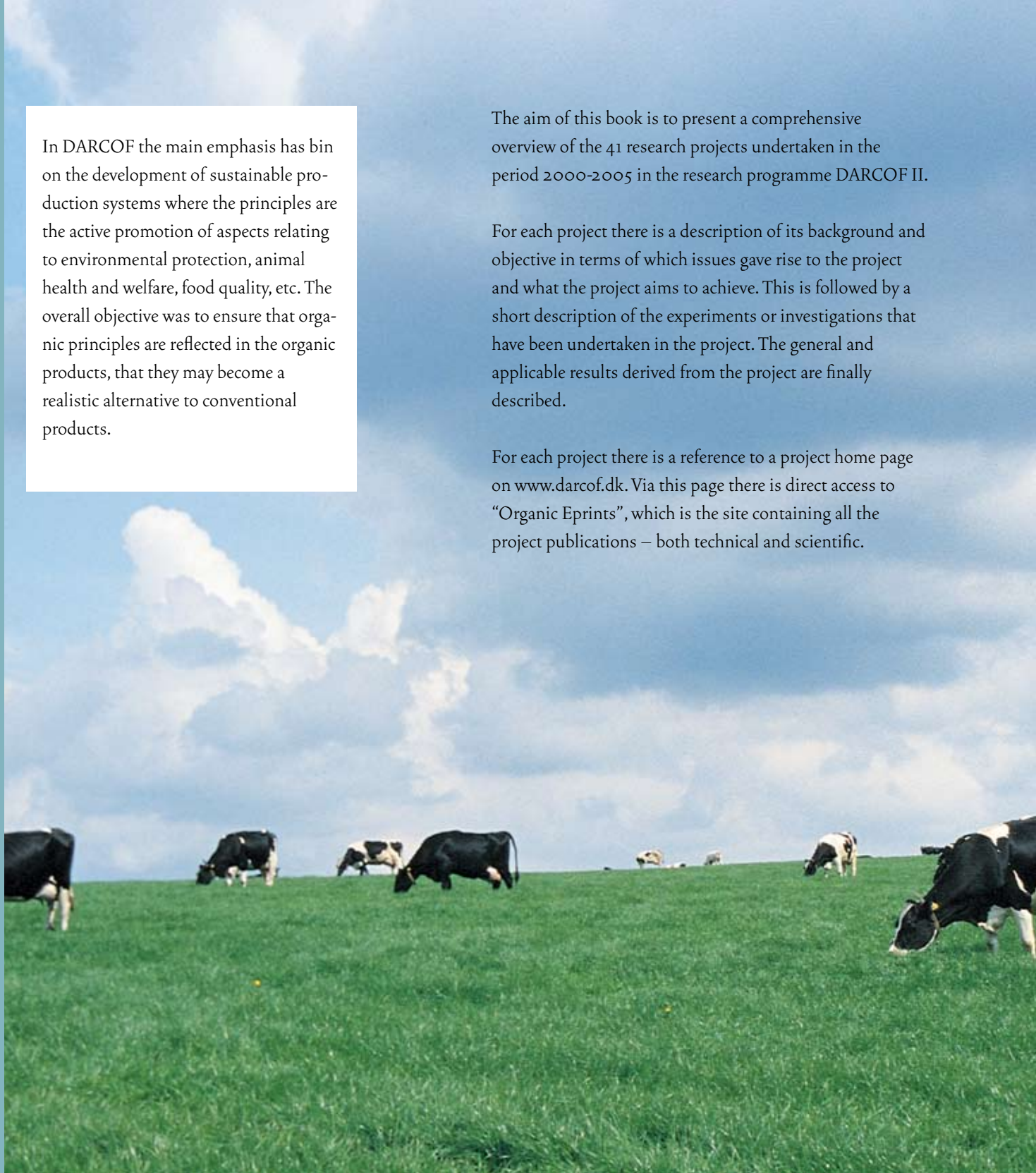
The roman numeral are project numbers, which are used as project identification

In DARCOF the main emphasis has bin on the development of sustainable production systems where the principles are the active promotion of aspects relating to environmental protection, animal health and welfare, food quality, etc. The overall objective was to ensure that organic principles are reflected in the organic products, that they may become a realistic alternative to conventional products.

The aim of this book is to present a comprehensive overview of the 41 research projects undertaken in the period 2000-2005 in the research programme DARCOF II.

For each project there is a description of its background and objective in terms of which issues gave rise to the project and what the project aims to achieve. This is followed by a short description of the experiments or investigations that have been undertaken in the project. The general and applicable results derived from the project are finally described.

For each project there is a reference to a project home page on www.darcof.dk. Via this page there is direct access to "Organic Eprints", which is the site containing all the project publications – both technical and scientific.



Organic Eprints

Organic Eprints is a so-called "Open access archive" where scientists working in organic production can deposit their articles and publications. The users of research have free access to the publications via the internet. The archive was established by DARCOF in 2002, but is jointly managed with the Swiss research institute FiBL and the German Federal Institute for Agriculture and Food (BLE).

The archive has become a great success and is daily visited by several thousand research users from all over the world, who are looking for research-based information on organic farming and food production.

Continuous flow of information

On www.darcof.dk it is also possible to subscribe to DARCOFenews, which is the electronic newsletter of DARCOF. DARCOFenews informs, for example, of the latest research results, seminars, open-farm days, etc. The newsletter is free and is published four times a year.

New research

There is finally access via www.darcof.dk to information on new research projects within organic farming and food production. In 2006 a new research programme, DARCOF III, will commence, which means that new research projects will regularly be started up.

Organic production of greenhouse vegetables

In organic farming vegetables have to be grown in soil, but the production of greenhouse vegetables directly on soil incurs the risk of large nutrient losses.

In a newly developed production system for greenhouse vegetables, an organic compost is used with a vegetable production on soil. After harvest, the compost can be applied to the field and there is an insignificant loss of nutrients compared with other cropping systems.

Yield levels are competitive, even in conventional systems, and there is no reduction in quality compared with other systems.

In greenhouse vegetable production, large quantities of plant nutrients are needed. In an organic production this can lead to problems. It can be difficult to provide sufficient nutrients from organic sources and there may be significant nutrient leaching when the crops are grown directly on soil. The nutrient supply is more difficult to control than in conventional production, why there may be occasional problems with quality. This, combined with a costly conversion process, has led to an increased interest in growing greenhouse vegetables in closed beds with no soil contact. The compost in the beds can be replaced and the drainage water collected. The conversion is also less costly as the equipment in the greenhouse to a large extent can be used.

However, many consider the growing of vegetables in closed beds to conflict with the ideology behind organic farming. The advantages of growing plants in soil with a diverse nutrient and trace mineral content are lost, as plant roots in soil can scour a large volume of soil and thus obtain a relative stable supply of water.

Combining the advantages of growing directly on the soil and the closed bed principle would therefore seem a natural thing to do. Most of the compost could, for example, be confined to a closed bed and the plants could develop their rooting system both in the bed and in the soil outside. Less compost would be added to reduce the amount of leaching, the drainage water would be collected and the compost regularly replaced to avoid the build-up of crop diseases.

Investigations in existing systems

The investigations have shown a considerable nutrient surplus and that in practice this is difficult to control without the risk of considerable losses. The results, however, also indicate that there is scope for improvements, both in the development of fertilization and cropping strategies, and, for example, in the grafting of tomatoes on a more efficient rootstock, which we were given the opportunity to study. Experiments on soil that had been cropped with organic tomatoes for 4, 10 or 15 years, showed no clear effects of 'organic age'. Large additions or organic material may have been counterbalanced by the faster turnover of nutrients under glass than outdoors due to the higher temperature and humidity, which can have a considerable effect on the nutrient value of slow-release organic manures.

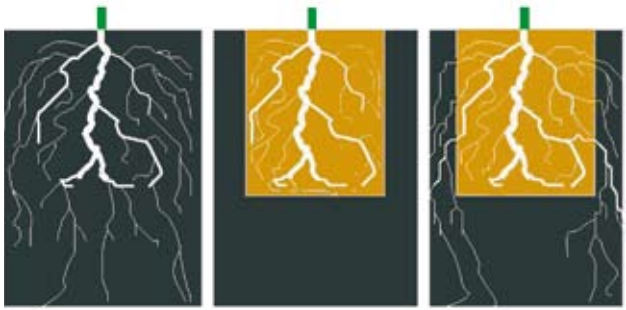
Quality controls showed no clear differences between organic or conventional tomatoes, but a considerable effect of variety and ripeness at harvest. Organic management is thus not in itself a guarantee of good flavour and quality, which have to be a management objective.

Production of plant-based compost

Large-scale composting experiments with wheat straw and grass/clover hay were initiated in the autumn 2001. In the experiment we tested the hypothesis that a delay in the addition of some of the nutrient-rich material would prevent a considerable immobilization during the decomposition

of the carbon-rich wheat straw. The results confirmed the hypothesis and showed that after 7½ weeks of composting there was twice as much available nitrogen in the treatments where the nitrogen-rich material had been added in stages.

The composting experiments showed that the compost was a suitable growth medium, but that it was too nutritive, why new composting experiments with a larger initial C/N ratio were initiated. The interesting results that show that the composting process can be controlled just by delaying the addition of an N-rich material give reason to believe that plant residues can form a nutritive compost that may be used as a growth substrate. Future investigations will therefore to a higher extent focus on the structure of the compost.



Left: *Cultivation on soil;*
Middle: *Cultivation in closed beds;*
Right: *Cultivation in a mixed system*

Development of production systems for tomatoes

In 2001 a preliminary study on the use of substrates in a closed bed tomato production was carried out. The study showed that the compost consisting of deep bedding material immobilised the nutrients from the start making it inaccessible to the tomatoes. The compost consisting of grass/clover hay, on the other hand, released many nutrients right from the start. Both substrates had a poor physical structure. Based on these results, we produced a growth substrate from a mixture of deep bedding, grass/clover and sphagnum. We have used this growth substrate in experiments with tomatoes in closed beds, directly on soil and in a mixed system. In the mixed system, the tomatoes are started off in closed beds, but their rooting system is left to spread to soil outside the beds. All treatments were given the same growth substrate. The mixed system gave the best results, but the differences in yield, growth rate and nutrient con-

centrations are not large. Later in the season we partitioned the plots and gave an additional fertilizer application of Lucerne pellets to half of each plot. Yield and nutrient levels indicate that there was a good effect of the treatment. The results also show that we can successfully grow tomatoes in closed beds, also later in the season and that much of their nutrient requirements can be provided in plant materials. Plant materials can therefore be used both as an important component of the initial growth substrate and as a later fertilizer application.

We conclude, that the mixed system works well and can be recommended. It has many advantages compared with the completely open system and gives comparable yields. The mixed system may not be as good as the closed system at reducing root diseases, but there is a high yield and the nutrient use efficiency is clearly better. The closed system also has some clear advantages, but it is difficult to control and will require further development before it can be used in practice.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/i1.html
and the internet-archive: www.orgprints.org

Sustainable production systems for organic apple production

Organic apples are often sold for fresh consumption and therefore have to obtain high quality requirements. The fruits must obtain the right size and be undamaged without important infections of pest and diseases. Apple scab causes brown or black spots on the fruits and severe infections can result in fruits not suitable for consumption. This disease causes big reduction in yield and quality in organic production. Copper is an effective fungicide to control diseases and is used in organic apple production in some European countries. Copper has not been permitted in Denmark the last 10 years and the European Union wants to reject it from the list of pesticides permitted in organic production. To improve the quality and yield in organic apple production, it is important to find the best culture techniques. Combinations of cultivars, nitrogen availability, rootstocks and planting distances are tried to prevent or reduce apple scab infections.

The organism that most often causes damage on the skin of apples is apple scab. Apple scab causes brown or black spots on the fruits and severe infections can some years result in fruits not suitable for consumption. This disease causes big reduction in yield and quality in organic production.
The yield at growers not using copper for apple scab control is only 0-50 percent of a conventional yield depending on the cultivar and the year. In average, the yield reduction was 86 percent compared to conventional production. Many organic apple growers use organic allowed pesticides to try to control diseases. Cobber is an effective fungicide to control diseases and is used in organic apple production in some European countries. Copper has not been permitted in Denmark the last 10 years and the European Union wants to reject it from the list of pesticides permitted in organic production. The break down of the genetic resistance towards apple scab in newly bred cultivars has decreased the possibilities for an economical rentable organic apple production.

Methods to prevent apple scab

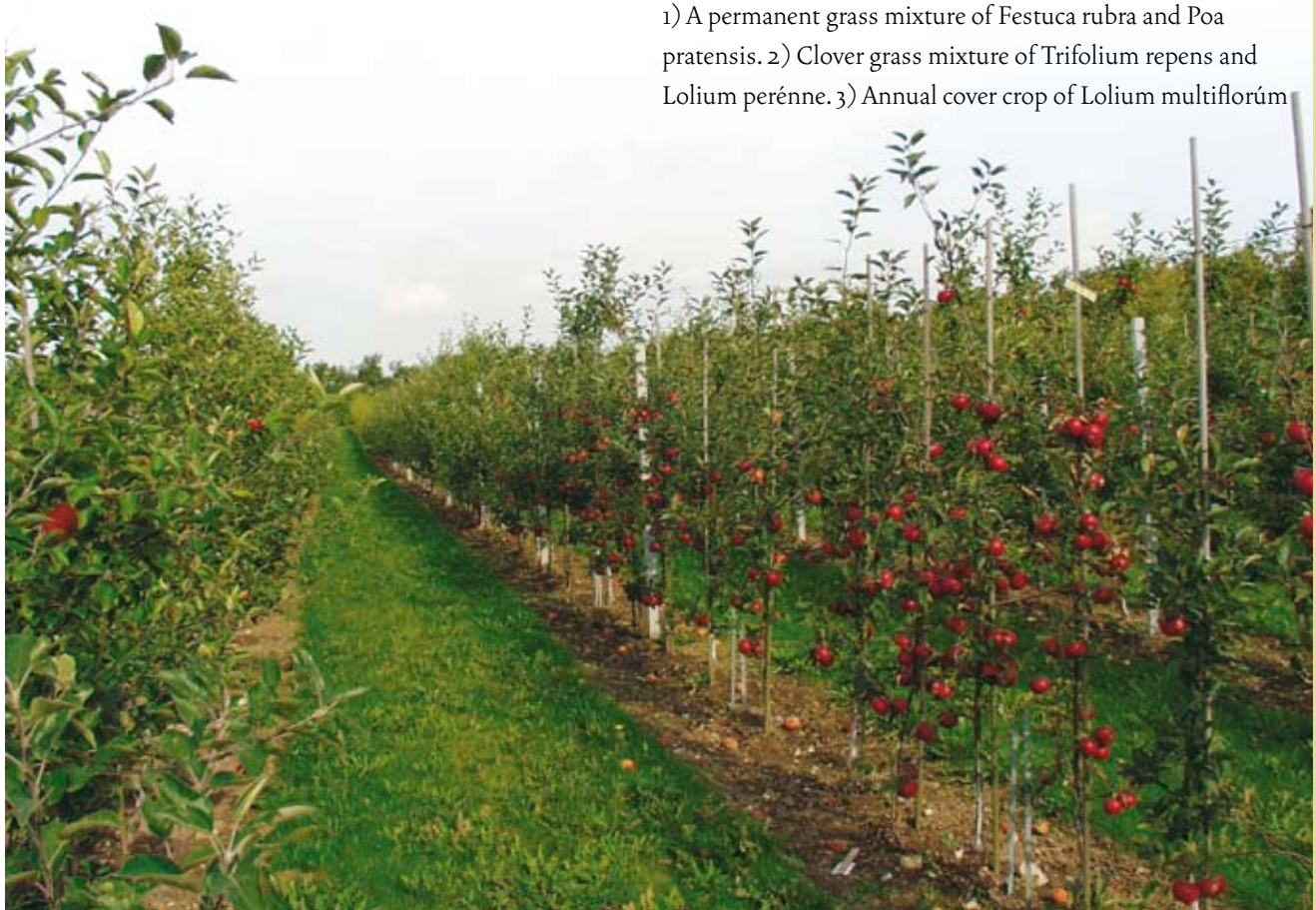
The most important method to prevent apple scab is to use genetic resistant apple cultivars or cultivars with less susceptibility to apple scab. Small, open rather slow growing apple trees reduce the possibilities for apple scab infections. A high level of available nitrogen in the soil causes increasing growth and an extended growth season. This gives better infection possibilities for apple scab. The increased level of nitrogen in the plants also causes a decrease in the content of phenols in plant tissue, which increases the possibility of growth for apple scab.

Mechanical weed cleaning in the tree row

To optimise organic apple production, the effect of combinations of fertilisation, rootstocks and planting distance on apple scab infection, yield and fruit quality has been investigated. The research has been carried out in cultivars with a low susceptibility but no resistance to apple scab. Control of apple scab has been carried out at big ascospore discharge periods. The warning program RIMpro has been used to predict these severe infection periods.

Effect of cover crop on fruit quality

The effect of cover crops on quality and yield of apples was investigated.
The following cover crops were established in the alleyways: 1) A permanent grass mixture of Festuca rubra and Poa pratensis. 2) Clover grass mixture of Trifolium repens and Lolium perénne. 3) Annual cover crop of Lolium multiflorúm



The same cultivar "Retina" grown at different nitrogen levels

and Trifolium resupinatum, sown every year in July. The soil has been kept black from April to July. In the tree row, the soil was mechanically cleaned and the trial was kept unfertilised and unsprayed. Fruits produced on trees managed with a grass alleyway (1) had a lower nitrogen supply to the trees and obtained the best skin coloration. A lower nitrogen supply, especially during fruit development, resulted in more red fruits. The apple scab infections were more numerous on apples grown in the annual cover crop (3). This treatment gave the largest nitrogen supply to the trees. Overall, the fruits from the grass alleyways (1) had the highest percentage of marketable fruits. Even though the gross yield was bigger from trees grown in the annual cover crop (3), the crop of marketable fruits was at the same level from the two systems. The reason was a higher percentage of disease infections on fruits grown with a higher nitrogen supply (3). The cultivars Otava, Prima and Florina produced the biggest yields. Vanda had the biggest fruits. The resistance to apple scab was broken down in most cultivars. The cultivars: 'Florina', 'Vanda', 'Retina' and 'Redfree' were less infected by apple scab. Only Florina was still fully resistant during the experiment.

Development of end buds in apples

Apple scab, which winters in the woody parts of the apple tree as conidia, is physically close to the developing of new fruits and leaves in the spring. It is very important to reduce the possibility of apple scab wintering in branches and buds. Early end of vegetative growth and development of end buds in autumn will reduce the possibility of late infection in autumn and thereby reduce the risk of spring infections form conidia in woody plant pates. End bud development depends on the cultivar and the rootstock. To know the end bud development of different combinations of rootstock and cultivars would mean to be able to recommend the earliest end bud development combinations for organic productions

and thereby reduce the infection risks of apple scab from woody plant tissue in the spring.

End bud development of 51 rootstocks showed that rootstocks with high winter hardiness also had the earliest end bud development. MM106 is a rootstock with poor winter hardiness and the latest end bud development of the 51 rootstocks. This rootstock is in several countries quite recommended for organic production, but as a consequence of these results, it should not be recommended to organic apple production. Surprisingly, the very vigorous growing Swedish rootstock A2 had an early end bud development. This rootstock is a potential good choice for an organic apple orchard where big trees or a vigorous growth is necessary. The weak rootstock M9, which is recommended for high planting density intensive orchards had an early end bud development and is also for that reason suitable for organic apple production. The Russian rootstock B9 is also potentially suitable for organic production due to week growth, high winter hardiness and early end bud development.

Intensively grown organic apples

In two big trials, the optimum level of nitrogen in the soil and plants in relation to the disease infection, fruit quality and yield, were investigated. The non-resistant varieties 'Discovery' and 'Ingrid Marie' were chosen. They can be infected by apple scab, but are recommended for organic production because they are less susceptible.

In 2004 and 2005, the fruit quality and yield are recorded. The fruit quality consists of both outer quality and inner quality. Outer qualities are fruit size, fruit colour and damages caused by pest and diseases on the fruit skin. Inner fruit quality is firmness and content of sugar and starch.

In the EU-project (QLIF), the sensory quality and content of phenols will be investigated in relation to the production methods and especially the nitrogen availability and planting density. Results of the projects will be used to optimise the recommendations for organic production.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/i2.html
and the internet-archive: www.orgprints.org

Models of nitrogen dynamics and crop production

Reliable simulation models of cropping systems can be used to aid the design of crop rotations and cropping plans, which optimises production. Model-based analyses can also be used for assessing the effects of crop production on the external environment, e.g. in relation to nitrate leaching.

Organic farming is based on complex interactions between plants and the soil biota, and many data are required for developing and testing models for these interactions. The project has improved two existing simulation models, which in different ways provide opportunities for modelling the effects of management on environmental impact. Further, a model has been developed for the effects of cropping strategies on soil fauna.

The production in organic farming and its effect on the environment depends on a complex interaction between biological, physical and chemical factors, some of which are strongly climate dependent. Scenario analyses using well-tested simulation models of crop rotations can be used to evaluate effects on production, soil fertility, biodiversity and environmental impact. However, the models should be based on a solid basis of data from both short- and long-term experiments. The project used three supplementary models, Daisy, FASSET and FieldEco.

Two of the models, FASSET and Daisy, are based on a description of soil nutrient pools and their dynamics, water movement and crop growth in the soil-plant-atmosphere system. FieldEco is based on a description of the soil fauna and its interaction with different levels of the food chain, the links between different populations and the effects on nitrogen release. The role of FieldEco was to estimate the effect of soil fauna on nitrogen turnover, availability of nitrogen for plants and the effect of cropping system on biodiversity of the soil fauna.

Model development, adaptation and testing

The three models, FASSET, Daisy and FieldEco, have been further developed, adapted and tested by comparing simulations with measurements from a range of observations from field and laboratory experiments. The models were tested against the following Danish field experiment:

- The Burrehøjvej experiment on conversion of grasslands,
- The nutrient management experiment on manure management in a dairy farm crop rotation,
- The crop rotation experiment on arable crop rotations with variation in manure application and use of catch crops.

The FASSET model

The model is with few adjustments capable of capturing the residual effects of different grazing systems, and of estimating the yields of the different crops for which experimental data were available. The model has also been able to capture observed fundamental differences in between treatments with different rates and types of organic manure and catch crops.

The adapted version of the FASSET model was used in the final evaluation of the Danish Aquatic Action Plan II (VMP II) for simulating the difference in nitrate leaching between organic and conventional plant production. A range of mitigation, scenarios to further reduce nitrate leaching

from organic and conventional cropping systems were also analysed. The results showed only small differences in nitrate leaching between conventional and organic arable crop rotations.

The Daisy model

The analyses using the Daisy model has focused on simulating 1) grass-clover and grazing, 2) the effects of the catch crop type on soil nitrate concentrations and simulated nitrate leaching, 3) comparisons between different models of soil organic matter turnover.

The simulations of the first three years of grass growth, grass-clover growth and grazing were calibrated, and the grass-clover model performed well for the tested sites and treatments. However, for simulating competing undersown crops, the model is too sensitive for a range of parameters, whereas it does not sufficiently well describe the residual effects after ploughing of grasslands.

The Daisy model was additionally used for simulation of vegetable crop rotations. These analyses primarily focused on the effects of rooting depth of catch crops and the location of catch crops in the rotation for nitrogen use and losses in the rotation. The results have confirmed that the root growth rate and the maximum rooting depth are of major importance for reducing soil nitrate concentration after several years of nitrate leaching. They can thus be placed strategically in the crop rotation, and not necessarily always in the place in the crop rotation with the highest risk of nitrate leaching.

FieldEco

The adaptation and testing of FieldEco were performed against data from the Burrehøjvej experiment and the simulations compared well with the observations. The model was used to evaluate the effects of earthworms on nitrogen dynamics in organic crop rotations. The simulations showed a 30% higher content of soil mineral nitrogen in scenarios with earthworms than without earthworms. The effects were highest in late summer and autumn. This confirms the

hypothesis that earthworms can play an important role for nitrogen dynamics in organic farming.

New model developed for soil organic matter

A particular focus was on modelling turnover of soil organic carbon (C) and nitrogen (N) in the two simulation models, FASSET and Daisy. Particular emphasis was put on systems with a large input of nitrogen in organic form, e.g. in nitrogen fixation in grazed grass-clover or in animal manure. The purpose was to improve the model for soil organic matter turnover in the Daisy and FASSET models.

For this purpose, we collected the world's largest collection of data from field and laboratory experiments on turnover of soil organic matter. These data have been stored in a database coupled with a model complex with modules for simulating, optimizing and graphic display. This has given a strong basis for developing a new model, CN-SIM. The results point towards a re-evaluation of fundamental parameters in many internationally well recognised soil organic matter models.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/i3.html
and the internet-archive: www.orgprints.org

Quality and production of bread wheat

Crop rotations with perennial grass pastures and frequent amendment of crop residues and animal slurry accumulate significant amounts of organically bound nitrogen in the soil with a concurrent risk of leaching to the environment. Better management of the release of this nitrogen in the growth season may enhance the nitrogen utilisation.

Good residual effects of grass pastures increased the yield and quality of subsequent bread wheat as compared to bread wheat grown in a grain crop rotation. Yield and grain quality could not be increased by soil tillage strategies.

Increased quality and production of bread wheat

In organic farming, a basic aim is to achieve an efficient utilisation of nutrients and minimal losses to the environment. Nitrogen (N) is the key nutrient for the production and quality of crops and also represents a potential environmental pollutant. The amount of plant available nitrogen is controlled primarily by the crop rotation and the amendment of manure and crop residues. Soil tillage and placement of liquid manure are potential tools to manage and control the release of nitrogen.

By studying the entire production chain from the soil to the baking, the present project has sought to establish an improved basis for an integrated advisory concerning nitrogen management in organic plant production – especially with the aim of improving the quantity and the quality of bread wheat produced in Denmark.

Residual effects of grass/clover pastures

We have studied four different grassland histories on loamy sand up to the 8th production year: unfertilized grass-clover and fertilized ryegrass that were either grazed with dairy cows or cut.

In the grazed pastures, the leaching was always lower from grass-clover than from ryegrass. The difference was moderate in the 4th and 5th production year, but was important in the years 6 to 8. In these years, the leaching from grass-clover

was only 9-13% of the leaching from ryegrass. The cause is that grass-clover in the first production year fixes 200-300 kg N per ha, and thereafter the fixation decreases. Thus, in the 8-year old pasture, the fixation was measured to ca. 100 kg N per ha. This is due to a regulatory mechanism in the grass-clover, implying that a higher content of mineral nitrogen in the soil reduces the level of nitrogen fixation.

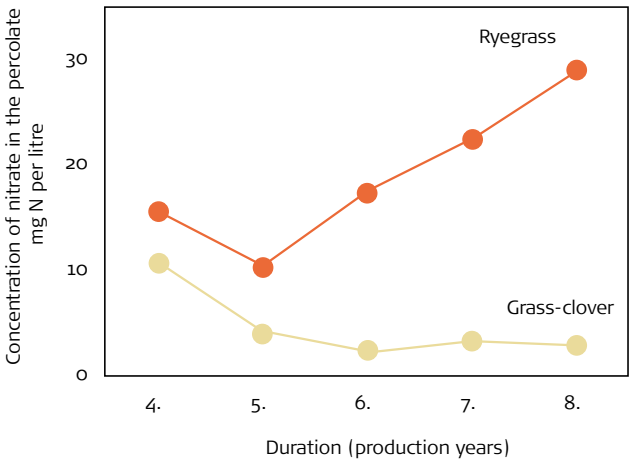

Figure 1. Concentration of nitrate in the percolate from grass/clover and ryegrass grasslands of different age

Likewise, the yield in the 8th year pasture was considerably reduced as compared to the first years. A lower clover-grass production resulted in less grazing and consequently less deposition of nitrogen in dung and urine spots.
The low leaching from the 4-8 year old grass-clover with grazing indicates that this production form is suitable, e.g., in areas that hold an interest as groundwater resources. Also, the good residual effect of the grass-clover causes that the yield and quality of subsequent bread wheat is highly improved as compared to bread wheat produced in an ordinary grain crop rotation.

Soil tillage

Soil tillage is generally done to prepare the soil for sowing or to incorporate plant residues and animal manures. However, mechanical weeding also results in some soil tillage. This mechanical disturbance of the soil expectedly enhances the mineralization of organically bound nitrogen in the soil. If so, a strategy of soil tillage during the growth season may stimulate the plant growth and contribute to a better quality

Row-rotavator in winter wheat

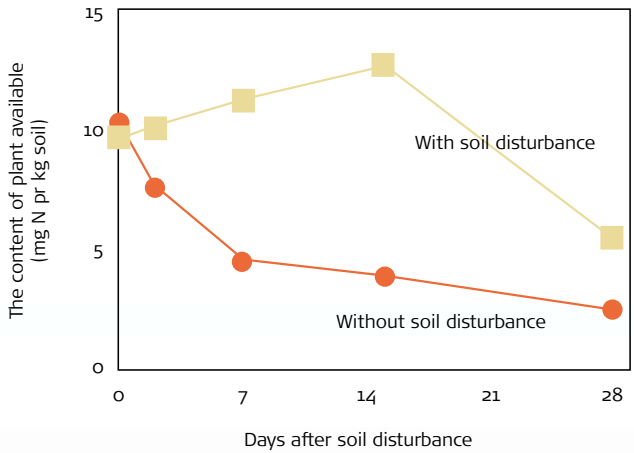

Figure 2. The content of plant available N in soil with and without tillage

of bread wheat. These possibilities of using soil tillage as an indirect nitrogen source has been studied in winter wheat. Soil between the rows of winter wheat was loosened to a depth of 6 cm in spring (May). The soil disturbance caused an increase in the soil content of plant available nitrogen as compared to undisturbed soil. Yet, the increases were modest and calculated to less than 10 kg N per ha. The increases may mainly reflect that roots damaged by the soil disturbance were unable to take up nitrogen at the same rate as in the undisturbed soil. This way, plant available nitrogen accumulated in the disturbed soil, whereas the wheat took up plant available nitrogen in the undisturbed soil.

The soil loosening did not significantly influence the grain yield and the nitrogen uptake. Thus, neither a higher yield nor a better grain quality could be achieved.

Influence of manure placement

Placement of manure may optimise the utilisation of nutrients and provide a better grain quality by increasing the N uptake by the crop and reducing the supply of nutrients to weeds.

Normally, nitrogen applied to increase crop productivity will also be available to weeds. However, production systems resulting in better crop uptake of the applied nitrogen will concurrently reduce N uptake by weeds.

Crop uptake of applied nitrogen is very intensive in a short period in spring following the fertilizer application. Depending on the method of application, different factors influence the relation between weeds and crop. Circumstances weakening the crop ability to recover applied nitrogen may also cause a change in the weed: crop

From baking test of spring-sown wheat grown after a grass/clover ley. The spring wheat received (from left to right) no, 115 or 230 kg N in slurry.

competition for other growth factors such as light and water. Moreover, the possibility will be reduced to achieve an effective and low-cost weed control, mechanical as well as chemical.

Quality of bread wheat

It is important to identify wheat varieties that are suitable for production of bread wheat in organic farming systems. Yet, for this challenge there is a lack of user-friendly methods for testing the quality of bread wheat. In cooperation with the other project activities the interaction between choice of crop varieties, nitrogen management and baking quality has been studied for organically grown wheat.

The results obtained so far have demonstrated problems with a low protein- and gluten content in organically grown wheat, but apparently some varieties perform better than the average.

Further, the results show that the type as well as the amount of animal manure affects the protein content of grains and the gluten content of the flour. At all levels of fertilizer, the use of liquid slurry resulted in a higher protein and gluten content whereas the bread volume was not significantly different for the two fertilizer types. Measurements of the quality of spring wheat, grown after ploughing of grass pastures, showed that the grass resulted in a good baking quality. The quality was equivalent to wheat grown with a supply of 150 kg N per ha in a system with precedent grain crops. Additional amendment of slurry increased the protein- and gluten content. The structure of the gluten became softer and more stretchable, but did not result in an increase of the bread volume.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/i4.html
and the internet-archive: www.orgprints.org

Fababean-wheat intercropping in farmers field

Cultivation of grain legumes in organic farming

From 2005, all feedstuffs must be organically produced. The main aim of the project has been to determine the potential for cultivation of more grain legumes (pea, faba bean and lupin) in organic cropping systems.

The results showed that intercropping of grain legumes and cereals produce a series of benefits e.g. yield advantages of up to 50% compared to sole crops of the same species, greater protein yield and improved protein quality. The growth of faba bean and pea was reduced in soils with limited availability of potassium and phosphorous, whereas lupin was unaffected.

Since all feed in organic farming must be of organic origin, increased local protein production is required to enhance the integrity of organic farming. Grain legumes pea, faba bean and lupin are suited for Danish growth conditions and they complement cereals in feed mixtures. Grain legumes have a second important role, namely to supply the organic rotation with biologically fixed dinitrogen. Despite of the many benefits, the cultivation of grain legumes has been limited. They have the reputation to be unstable crops due to drought sensibility, lodging and late maturity.

The aim of the project was to evaluate the potential for increased cultivation of grain legumes in organic cropping systems, including intercropping of grain legumes and cereals. We investigated the effects of soil type, climate, potassium- and phosphorous availability and the effect of intercropping on weeds and plant diseases. Simultaneously, biological nitrogen fixation, nitrogen balances, available nitrogen in autumn and nitrogen for the subsequent crop were determined. Furthermore, the quality of grain legumes and cereals in relation to feeding of pigs and poultry was investigated.

Choice of grain legumes

Independent of the cereal species (barley, triticale and wheat), which were components in intercropping, a homogenous development and maturation were observed for all tested cultivars of pea and non-branching lupins. In some years, faba beans and branching lupins were unsuited for simultaneously harvest of intercrop species. The greatest grain yields were found in barley-pea intercrops, but the greatest protein yields were found in sole crop lupin. The amount of nitrogen in crop residues and the amount of fixed N were less in pea compared to faba beans and lupins. This reduced the nitrogen balance in pea-grown soil, although it was still positive. The pea and faba bean yield stability was low on sandy soils, whereas pea on clay soil showed a good stability. Faba bean and non-branching lupin sole crops were bad competitors against weeds. This ability appeared to be less important in intercrops with cereals, when the cereal is developing normally and is able to compete against the weeds.

On the sandy soil, the preceding value to winter wheat of faba bean and lupin, grown as sole crops, was higher than after barley sole crops and pea barley intercrops. Sole cropped grain legumes should always be followed by an autumn established and over wintering crop on sandy soil to reduce the nitrogen losses. No difference was found in the preceding effect of sole or intercropped grain legumes on the clay soil.

Effect of low potassium and phosphorus availability on grain legume growth

Faba beans and pea had the requirement for supplemental potassium supply when they were cultivated on a sandy soil with low potassium status. The yield of lupins was unaffected by potassium status. Symptoms of deficiency were detected in pea, and faba bean plants were lower at limited potassium availability.

Choice of lupin cultivar for improved complementarity

Pea-barley intercropping and interspecific competitive interactions

Similarly, a large effect of phosphorous supply was measured in pea and faba bean but not in lupins. Intercropping of barley and grain legumes resulted in yield advantages at the lowest P level. The advantage was greater for intercrops of pea-barley and faba bean-barley than of intercrops of lupin and barley. On clay soils, phosphorus and potassium were utilized up to 28% more efficiently in the intercrop compared to the species growing as sole crops. The mechanisms of P and K uptake in lupin may differ from those of uptake in pea and faba bean.

Measurement of light and water use showed that water availability at clay soils does not seem to be important for the competition in and growth of crops. On the other hand, the competition for water at sandy soils, especially during early development, causes considerable yield reductions especially in pea and faba bean and to a lesser extend in lupin. The better ability of barley to absorb light, compared to pea, also turned out to be an important parameter of competition.

Comparisons of inter- and sole cropping strategies

Intercropping of grain legumes and cereals

Grain yields were on average (2001-2003) 12-53% greater when species were intercropped compared to sole cropped. It was especially pea-barley and faba bean-barley intercrops, which improved the use of light, water and nutrients. Simultaneously, the grain legumes were forced by barley in the intercrops to enhance the proportion of N fixed. This gave up to 40% better utilization of the soil N sources compared to sole crops. The crop N balances showed that the intercrops generally was not bale to increase the soil N level in the longer perspective, except for faba bean and lupin grown as sole crops. Pea, grown as a sole crop, showed a poor competitive ability towards weeds. The weed biomass was increased when the proportion of pea was increased in the intercrop: both barley and wheat were better to compensate for low plant number by increased tillering, which was not the case for the grain legumes.

Plant health

Intercropping of grain legumes with barley caused significantly less disease in the crops. The reduction was stronger the more different grain legume species were part of the intercrops. Pea Ascochyta blight was reduced with 25% by intercropping with barley, but with intercropping with barley, faba bean and lupin, it was reduced by 40%. Plant diseases are specific for the individual species. As a result, the spread of diseases (especially fungi) is reduced in intercrops, since the distance to the closest host is greater

than by cultivation in sole crop. The not-susceptible crop species for a specific disease can as one example constitute a physical barrier, which reduces the spread of the disease. The experiments also showed that intercropping is a good method to reduce the occurrence of seed-borne diseases. This is important by the production of organic seed. Nitrogen can be a limiting factor for plant production in organic farming. Experiments showed that supply of nitrogen can reduce the effect of intercropping, especially for barley net blotch. Generally, mildew and rust were increased by addition of fertilizer N. The research showed how the accessibility of crops to nitrogen, phosphorous and potassium influenced the establishment and growth of the mildew fungi. Especially, ratio between potassium and nitrogen influenced the susceptibility of barley.

Quality of the harvested crop

The nitrogen concentration in barley grain was greater after intercropping with pea and faba bean than in sole cropped barley. Lupin intercropping did not enhance the nitrogen concentration in barley irrespective the soil type. This was also the case for faba bean on sandy soil. There was no measurable effect on the standard feed quality on the grain legume seeds. Studies of samples with low and high protein concentrations showed that the biological value of the protein was reduced, when the protein concentration was enhanced. This was not the case for the barley cultivar Lysiba (high lysine), where a greater protein concentration increased the digestibility of the protein.

Intercropping spring wheat with either pea or faba bean increased significantly the protein concentration in wheat, especially with pea. The supply of nitrogen (urea) to sole crop wheat also increased the protein concentration, but not to the same degree as intercropping. An increase in protein concentration in wheat had apparently no negative effects on a series of other parameters for baking quality.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/i5.html
and the internet-archive: www.orgprints.org

Cultivation of row crops

Ridge tillage is a well-known alternative to ploughing in USA where it reduces the need for fertilizers and pesticides in conventional farming. The tillage system has not previously been tested or adapted for organic growing conditions in Denmark.

Ridges established in late autumn or winter may reduce N leaching and increase the amount of plant available N in spring. Incorporation of farmyard manure in ridges in late autumn may increase the yield of the subsequent crop compared to ploughing. Subsoiling in potato in the growing season has the potential to increase yield considerably. Maize, soybean and faba bean grown on ridges showed promising results, but there were no significant effects of mixing species (potato and faba bean) or cultivars (potato) in order to reduce diseases and pests.

New methods for row crop production

Ridge tillage, which is a more gentle tillage system than ploughing, makes it possible to incorporate manure and crop residues in the upper soil layers. Compared to other non-inversion tillage systems, it offers better possibilities for mechanical weed control. When ridges are formed, the most fertile soil is moved into the ridges. To a certain extent, precipitation will run down the sides of the ridges and thereby protect inorganic nitrogen within the ridges from leaching. Since ridge tillage also increases drainage and the soil temperature in spring compared with conventional tillage, it may also favour germination and early crop growth.

The project was inspired by two key principles in organic farming: Nutrient cycling and prophylactic measures against weeds, pests and diseases. To develop improved cultivation techniques for row crops, the following methods have been tested: 1) Ridge tillage as an alternative to mouldboard ploughing, 2) subsoiling during the growing season, and

3) mixing species and cultivars. The main focus has been on potato. As ridge tillage was investigated on different soil types, with and without catch crops, and with different types of manure, potato quality and Rhizoctonia stem canker was emphasized, because both are affected by the afore-mentioned factors. Also, interactions between irrigation and subsoiling in potato on sandy soil, the influence of potato variety mixtures and mixing faba bean into potato on late blight development, were investigated.

Effects of ridging

On sandy soil, ridges established in winter increased plant available nitrogen in the 0-50 cm soil layer by 8% in spring compared to ploughing, but crop yield was unaffected. Ridges and ploughing both gave an average total crop yield of 290 hkg/ha, which corresponded to 150 hkg/ha marketable yield. Tuber quality was improved insignificantly by ridge tillage. On loamy soil, there were no significant differences on crop parameters.

The effect of ridge tillage on N-leaching in winter was investigated in two separate series of experiments. In the first experiment, bromide was used to simulate nitrate transport in ridges. The experiment showed that in untrafficked furrows, leaching below furrows was 100% higher than below ridges. Hence, the study supported the hypothesis that ridge tillage protects nitrogen from leaching by reducing percolation through the ridges.
To get direct measurements of the leaching on both sand and sandy loam, the second series of experiments was condu-

cted in lysimeters. In October, solid farmyard manure was incorporated into ridges or ploughed in. Lysimeter leachate was sampled continuously from November to April and subsequently, a barley crop was planted on flat soil after levelling the ridges in spring. Ridges reduced leaching by 29% on sandy loam and 14% on sand during the wet winter of 2001-2002. In the very dry winter of 2002-2003, leaching was reduced by 13% on sandy loam, whereas there was no effect on sand. Spring barley yield after ridges was 20% higher on sandy loam and 13% higher on sand in 2002. In 2003, ridging increased the yield by 10% on sandy loam, whereas there was no effect on sand. Barley yield was increased by 17% in 2002 and 8% in 2003. The yield increase was highest on sandy loam. In a similar experiment with incorporation of animal manure on field scale, there was no effect on subsequent sugar beet yield. Based on these experiments, it is concluded that ridging in winter can be used as a measure to reduce N-leaching on sandy loam, whereas ridging in early autumn cannot be recommended as it may increase N-leaching potential, especially on sand.

Effects of subsoiling

A series of field experiment was conducted on sandy soil from 2001-2003 to determine the effect of inter-row subsoiling on potato yield and quality. Inter-row subsoiling in the growing season significantly increased marketable potato tuber yield by 49% in the dry growing season of 2001 but had no effects in 2002 and 2003. There are several potential reasons for this: 1) Precipitation levels immediately before

and after subsoiling were much higher in 2002 and 2003 compared with 2001. Thus, subsoiling was not performed under optimal conditions in 2002 and 2003, since subsoiling will compact the soil instead of loosen it, if the soil is too wet, and loosened soil will collapse if rain is falling immediately after subsoiling. 2) Crop growth stages at the time of subsoiling may have been different between the years and the ability of subsoiling to break off sprouts/stems, resulting in fewer, but larger tubers, is dependent of crop growth stage. 3) Subsoiling may also have a positive effect on crop growth by increasing nitrogen availability. The positive effects of subsoiling found in the first experiment year are most likely determined by a combination of these factors. However, it is not possible to determine which factor is most important and the question remains on how to reproduce a higher yield. As long as we do not fully understand the mechanisms involved, we will experience higher yields in some years and lower yields in other years. Further studies are warranted to investigate if it is possible to control the effect of subsoiling by timing the subsoiling operation according to crop growth stage and precipitation levels.

Pests and diseases

Mixing species and cultivars did not give any reductions in potato late blight high enough to be interesting for organic farmers. Faba bean was intercropped with potato to investigate whether faba bean could serve as a physical barrier against late blight and whether faba bean aphids would be simultaneously reduced. However, it was not possible to show positive effects of mixing potato and faba bean as regard to late blight and aphids on faba bean. Furthermore, it was not possible to prove any impacts of soil tillage, manure and catch crop on R. solani in field experiments with low and natural infestations. However, in 2003, different catch crops reduced severe attack of R. solani by about 50% in experiments with artificial inoculation.

Promising results with ridge planting of several row crops
In 2003, pilot studies with ridge planting of various crops were conducted. A number of interesting observations were made. Emergence of soybean planted on ridge sides had increased by 32% compared with flat soil. Dry matter weight of maize harvested in August had increased by 79% on ridge sides and 49% on ridge tops compared with flat soil. Also sugar beet, oat, barley, faba bean, lentil, lupin and pea were planted on ridges but maize and faba bean showed the highest growth increase. The experiments were repeated in 2004, and again ridge planting showed significant advantages for maize. The yield of ridge planted maize harvested in October had increased from 8.0 to 12.8 tonnes per hectare compared with flat soil. The reason for this dramatic yield increase is not known, but several factors may contribute: 1) use of ridges increases solar absorption and/or wind shelter, which in turn may increase soil temperature, speed up germination and increase mineralization and early crop growth, 2) ridges may increase drainage, reduce downwashing of nutrients and reduce water logging, 3) looser soil in the ridges and greater soil surface may improve aeration and root growth. Faba bean planted on ridges had a larger root system and bigger nitrogen fixing root nodules than faba bean planted on flat soil. The promising results from these pilot studies make it relevant to perform a thorough investigation of the potential for ridge planting of various row crops in organic farming.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/i6.html
and the internet-archive: www.orgprints.org

Soil quality in organic farming

Compacted soil below the ploughing depth is an increasingly widespread problem for farmers. The investigations in this project show, however, that only in very severe cases of compaction mechanical loosening of the subsoil should be used. Even when minimizing recompaction of mechanically loosened soil, root growth may be inhibited for several years after the treatment.

A versatile crop rotation and the application of animal manure are important instruments in the maintenance of soil fertility for organic farmers. The results of the project show that both management measures applied for only a few years can improve soil conditions in an exhausted soil. The investigations also show that soil compaction can reduce the beneficial effects achieved with other management measures.

What is soil quality?

Soil quality is how well a soil does what we want it to do. In other words, there are two things we have to consider – both what it is, we wish to achieve and how well the soil is able to fulfil our requirements. You often forget the first aspect, i.e. to define the objective sufficiently clear.

It is important that the *plough layer soil* is friable. That means that it crumbles easily when tilled but without total disintegration. The soil should also be able to resist the formation of a surface crust after precipitation, it should have a wide range of soil pore sizes, retain excess precipitation without giving rise to surface runoff (erosion), accommodate a more extensive rooting system and transport air to plant roots. The *subsoil* should be able to transport air and water, and it should function as a habitat for roots and living soil organisms.

Options available to farmers – project focus

Pioneers in the organic farming movement have emphasized the benefit of minimized soil tillage. This is to facilitate the function of the natural ecosystem processes. On the other hand, there is a need for operations such as weed control and the incorporation of animal manure and plant residues to take place. What is the minimum level of soil tillage required to do this and is it possible to have ploughless tillage in organic farming? Compaction of soil strata below the plough layer is an increasing problem – also in organic

farming. Should mechanical tools be used to loosen the soil and how do you best prevent recompaction? Crop rotation and the application of organic manures are the most important instruments for maintaining a friable and fertile soil in the plough layer. But which is the most effective? And to what extent will traffic and intensive soil tillage operations counteract the beneficial effects of plants and organic manures? These are the questions that we asked ourselves in this project.

Soil tillage in organic farming

A number of field trials with different soil tillage operations were carried out in the period 1996 to 2000. The investigations took place in a five-course crop rotation consisting of barley/pea with undersown catch crop, 1st year grass/clover, 2nd year grass/clover, oats and winter wheat. Four different soil tillage operations were investigated: two systems with ploughing to respectively 20 and 10-12 cm, and two systems with non-inverting loosening of the soil to 35-40 cm depth. For the soil loosening, heavy-duty winged tines mounted on a heavy frame were used, which also enabled the attachment of a Howard rotary harrow, a conventional Nordsten coulter section and seed drill. The conversion of the pasture was in all systems carried out with traditional ploughing to 20 cm depth.

The systems with mechanical loosening to 35-40 cm depth required a high power input but in return gave a very effective loosening of a compact plough pan, which was manifested in e.g. the number of rhizobia. The tillage methods investigated did not result in any noticeable changes in weed problems. Neither were there any clear effects of tillage on crop yield. There was a tendency for ploughless tillage to give a somewhat higher raw protein level in wholeseed and grass/clover yields than with ploughing.

Weed problems in ploughless systems may be more severe in other crop rotations than in the one studied here. We therefore conclude that the plough will continue to be required in organic farming, due to the need to incorporate perennial crops and straw-rich farm manure etc. Instead of a full conversion to non-inverting soil loosening, it may be realistic to reduce the plough depth as much as possible.

Organic soil, which has never been influenced by traffic

Mechanical loosening of dense subsoils

Many years of ploughing with the tractor wheel in the furrow and traffic with heavy machinery has led to widespread and increasing problems with harmful compaction of the subsoil in Denmark. There is a wide range of tools available that are fairly effective at loosening compacted subsoil – that is if the operation is performed in dry conditions. Nevertheless, most experiments still show that subsoiling gives a small and usually short-term effect on yield and soil structure.

In the project, we investigated the residual effect on yield and root growth of the aforementioned mechanical soil loosening to 35-40 cm depth. The crop rotation allowed a two-year grass/clover for silage to stabilise the soil and prevent recompaction of the loosened soil in non-trafficked areas. We then tested the effect on recompaction by different management procedures in two years of cereal growing. High axle loads were compared to small loads, and on-land ploughing was compared to traditional ploughing. The experiment showed that on-land ploughing was needed to prevent the re-establishment of a plough pan in the loosened soil. With traditional ploughing methods, the plough pan is quickly re-established.

In general, roots developed better in soils that had not been mechanically loosened than in soil with loosening to 35-40 cm. There was also a tendency towards higher yields in non-loosened soil. The roots apparently find it difficult to grow in subsoil where there are no old root holes or earthworm channels. Measurements also showed that the two-year grass/clover in combination with the subsequent use of on-land ploughing had a favourable effect on the non-loosened plough pan ("biological soil loosening").

The experiments thus show, that mechanical loosening of the soil under the plough layer is problematic and should only be contemplated in cases of very significant compaction. There should be further investigations of the feasibility of ameliorating the damage caused by compaction through the use of crops with strong roots ("biological soil loosening").

A friable soil in the plough layer

We know that a diversified crop rotation and the application of animal manure promote a number of soil qualities. In the project, we compared 1) a 'lean' cereal crop rotation with no animal manure applications, 2) a versatile crop rotation for forage, - also with no animal manure applications, and 3) a 'lean' cereal crop rotation that included animal manure applications. On this basis, we were able to determine their relative effect on soil properties. We also compacted half of the plots 'wheel by wheel' in order to determine the impact of mechanical compaction on the effects of crop rotation and animal manure.

The reported investigations took place on a loamy soil that suffered from organic matter depletion and had a poor tilth when the crop rotation experiments started in 1996. Our measurements show that both the versatile crop rotation and the animal manure applications increased the concentration

The plant to the right is affected by soil compaction

of biological and mechanical mechanisms that are active in the formation of soil tilth. One example is the proliferation of fungal hyphae that acts as 'biological threads' to bind the soil into aggregates, on which particularly the versatile crop rotation had an effect. Polysaccharides form a chemical bonding agent in tilth formation and our investigations show that both a versatile crop rotation and the application of animal manure increase the extent of these 'glues'. The improvement of soil tilth was also reflected in a larger microbial biomass. The investigations finally show that both types of enhanced management gave rise to a higher volume and tortuosity of soil pores.

In plots where the soil had been compacted in the autumn as part of the investigations, the soil was cloddy and difficult to till. This tendency was, however, reduced in plots with a versatile crop rotation and in plots receiving animal manure, although the compaction effect on all measured soil parameters was still strongly negative. There is therefore every reason to minimise traffic in organic farming. This can be achieved by better planning of field operations (including combination of field operations), the use of wide low-inflation tyres and the possible use of permanent wheel tracks for certain field operations.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/i7.html
and the internet-archive: www.orgprints.org

Management of perennial weeds

The perennial weed species common couch-grass (*Elymus repens*) and creeping thistle (*Cirsium arvense*) are causing increasing problems in organic farming, especially on stockless farms. However, new research has shown that strategic use of mowing, tillage and competitive crops can reduce perennial weed problems rapidly and substantially. The results have in particular been promising against thistle. A new weeding strategy to disintegrate and uproot couch rhizomes has been studied with encouraging results, but re-growth of shoots had to be suppressed by e.g. a competitive cover crop to obtain sufficient control.

Thistle problems have increased in Danish organic cropping in recent years. The extensive root system of thistle means that this species is capable of fast and expansive propagation within a few years' time. However, a research project undertaken at Flakkebjerg Research Centre has shown that even heavy thistle problems can be controlled through an applied effort.

The research at Flakkebjerg has focussed on weeding strategies that are applicable in organic cropping. For example, mechanical tactics either applied solely or in combination with the subsequent growing of suppressive cover crops have been studied. Two examples of strategies against thistle studied are given here.

Creeping thistle in an organic field. Thistle problems may expand rapidly

The effect of repeated mowing

In one experiment, repeated mowing was conducted every fortnight in a clover grass mixture from mid May to mid July. Spring barley was established in the experiment in the subsequent year, and the effects of the mowing conducted in the first year were obtained on the basis of thistle biomass and crop yield data.

The results showed that frequent mowing reduced the thistle population substantially, while preserving crop yield. The high re-growth capacity of clover grass after mowing had a strong suppressive ability against the re-growth thistle shoots. Crop yield in the subsequent year also benefited from the nitrogen that the clover grass had left behind. The experiment was repeated again in 2002/2003.

The effect of repeated hoeing

In another experiment, hoeing replaced mowing as the method to prevent thistle growth. The treatments followed the same scheme as that for the mowing experiment. However, the experiment was conducted in spring barley sown at 24 cm row spacing to make inter-row hoeing possible. A clover grass mixture was undersown in barley.

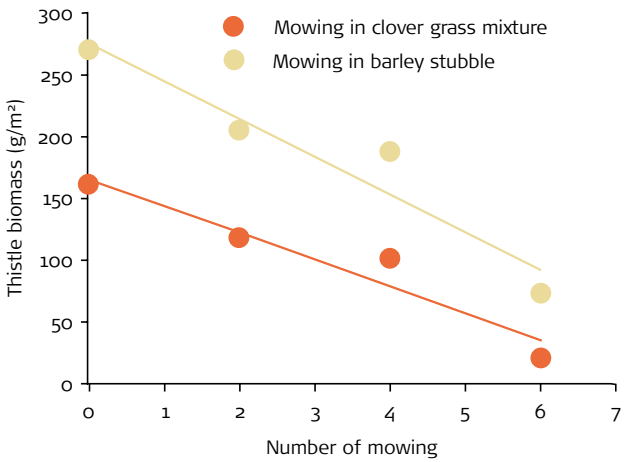

Figure 1. Thistle growth after repeated mowing the previous year. Mowing was done in barley stubble with or without a clover grass mixture.

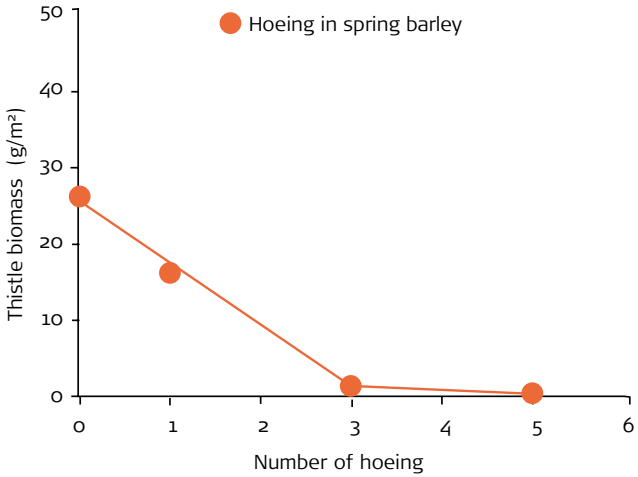

Figure 2. Thistle growth after repeated hoeing in spring barley in the previous year.

Spring barley was sown in the experiment in the subsequent year, where the effects of previous year's hoeing strategies were evaluated.

Hoeing in spring barley had a strong effect on thistle growth, which had been reduced markedly in the following year. However, crop yield did not benefit from the reduction in thistle biomass, probably because the thistle infestation was generally not high enough to suppress crop growth to a detectable level.

In general, these experiments have shown that even heavy thistle infestations can be reduced significantly over a 2-year period. The strategies also have relevance in acting as more preventive measures against lower thistle infestations where mowing/hoeing may be applied less intensively. The basis of these strategies is the application of mechanical disturbance of thistle growth followed by the growing of competitive crops to suppress thistle re-growth. The intensity of mechanical disturbance is adjusted according to the seriousness of the thistle infestation.

A new strategy for couch control

Traditionally, couch is controlled by repeated stubble cultivation from late summer and through most of the autumn. However, post-harvest tillage leaving the soil bare is undesirable in organic farming due to the need for retaining nutrients in the cropping system. The soil is mostly cropped in that period, limiting post-harvest tillage. Therefore, the

Disintegration and uprooting of couch rhizomes by means of a newly developed implement named "Kvik-Up harrow"

present project has looked at control strategies that merge the objectives of achieving a significant reduction of E. repens while having the soil covered with plants during the post-harvest period. Basically, the strategies consist of rhizome fragmentation and uprooting by soil cultivation of different duration after harvest of a main crop. Subsequently, a catch crop is grown to suppress shoot growth from the weakened and desiccated rhizome fragments.

The results have been quite variable with effects ranging from 0 to 60% reduction in couch biomass in the subsequent year. Especially, the success of establishing a dense and competitive canopy of the catch crop turned out to be very decisive for the suppression of couch shoot re-growth. Unfortunately, dry spells in both years of experimentation affected catch crop growing negatively leading to poor canopy development.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/i8.html
and the internet-archive: www.orgprints.org

Band steamer and steam generator on trailer

Band heating for weed control

Organic farming needs development of new rational methods for weed control. It is important that the systems invented have a minimum of energy input.

A prototype machine for band steaming of the soil before sowing has been developed. The system has been analyzed under field conditions in the years 2002-2004 and the results show that it is possible to gain a 95% effect in weed control. Energy consumption was app. 400 litres of diesel oil per hectare. The system analysed included a row spacing of 50 cm's and a dimension of the treated bands of 10 cm's width and a depth of 5 cm's. About 4000 litres of water was needed for the transfer of the energy from 400 litres of oil by steam into the soil.

The objective for the project has been to develop an integrated machinery system for thermal soil treatment in a narrow band around the crop row in a way that the germination of weeds can be destroyed using a minimum of energy. An intensive control of the process has been designed to maintain an effective weed control in the crop rows. Between the rows, weed control is carried out using precision hoeing. This system makes weeding by hand unnecessary.

The thermal row treatment creates an ideal basis for the use of automatic steering systems as the crop is easily seen and can be detected on the bare soil in the treated bands. It is analysed how to combine the system with precision sowing. In horticulture, a system is used in which treatment of the total soil surface prevents germination of the weeds. Compared to this system, a considerably better economy in energy consumption is reached using treatment in bands. The harm to the fauna of the soil is limited to the narrow intra row bands.

During the initial phase of the project, a special setup was designed in the laboratory. Batches of soil were processed at various temperatures and periods. Analyses of the thermal process show, that a certain period of heating of the soil is needed. It could be obtained by a lesser superheating, followed by a natural cooling of the soil. For this reason, it is not appropriate to build in the sowing machinery with the thermal system. A navigation- and steering system is needed for the sowing equipment to make sowing possible on the centreline of the treated bands. It is also important that the sowing is accomplished without pollution of the treated soil. In the accomplished experiments the sowing was carried out with a one-row manual drill.

Creating prospects for obtaining the wanted effect in weeding using the lowest possible amount of energy has been the main effort within the project.

The research is divided into 3 main tasks:

1. Engineering for thermal band heating
2. Biological analysing
3. Precision sowing

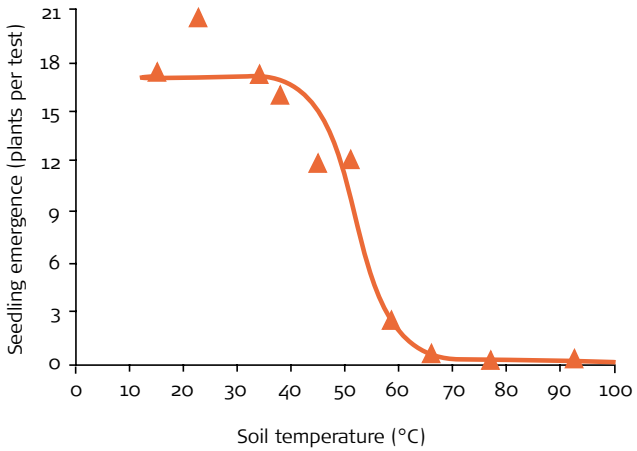
Effect of the system on weeding

The system for weed control is documented by laboratory test. A series of soil samples were heated in a homogeneous progress, obtained by stirring during heating.

The results show that during controlled conditions, an effect higher than 98% can be obtained in a soil with seeds from common weeds. The results are obtained by steaming the soil to a maximum level of 90°C, followed by a cooling procedure where the temperature is decreased by app. 100C after 10 min.

Impact from band heating on the ecological environment in the soil

In 2003, an associated project was carried out, analyzing the effect of band steaming on the germs and fungi in the soil. As expected, the results show a negative effect on the soil flora and fauna but against expectations, regeneration happens quite



Results from lab tests

slowly. These results support the aim of optimizing the process control, in order to carry out the treatment in the narrowest bands possible. The impact on the processed soil volume has a positive aspect as well: Steaming neutralizes possibly harmful fungi.

Testing a 'steamer'

On the basis of the results from the lab and the experiences from the field tests, 3 different proto type machines for applying steam to the soil were constructed to conduct a series of field tests. The results prove that it is possible to conduct a homogeneous heating of the cross section in the steamed band. Compared to the lab test, a faster cooling is observed, especially in the soil surface.

Energy consumption

Energy consumption during the field tests is measured to app. 400 l diesel oil per ha. A cost benefit analysis shows an economical break-even in a 4 ha production area with carrots or onions.

Precision sowing

Results from the study of precision sowing and (RTK) geo-positioning show that the system in principle is practicable. However, the results from the field tests show that the uncertainty concerning the position of the individual seeds and plants is too big for marketing within precision hoeing. The Agro-Technology Group at The Royal Veterinary and

Photo of a test plot 2004:

Numbered from left to right, the intra-row bands have been treated with:

1. *70°C – I*
2. *0°C – I*
3. *70°C – II*
4. *80°C – II*
5. *90°C – II, hand weeding*
6. *0°C – II, hand weeding*
7. *90°C – I*
8. *90°C – II*
9. *80°C – I*

The stated temperature is max. temperature of the soil surface. I and II correspond with low and high intensity in soil preparation performed by the band steamer

Agricultural University continues the work concerning the technology in other projects.

The new system in the future

The technical and agronomical research in the process applying steam to the soil has had a satisfactory progress. The results meet the expectations due to the fact that within the project period, equipment has been developed, which can be used to implement thermal band heating, resulting in the wanted weeding effect. The market analyze as well showed that the system is considered attractive from an economical point of view. Considering the negative side effects in the form of consumption of fossil energy and influence on the ecological environment, one must bear in mind that the process eliminates the demand for manual weeding, which often amounts to 100 man-hour per ha.

In 2005, the system was approved by the Danish Plant Directorate fore use in organic production. The steamed band must cover a maximum width of 15 cm's and the un-steamed area between the bands must cover a minimum of 2 x the width of the steamed band. After the approval of the system, the company C.O. Madsen Specialmaskiner has supplied a 4-row machine to a producer of ecological carrots.

Further development is needed to solve the problem with clay soil sticking to the inside of the band steaming machine. Technology for automatic control of the heating temperature should be developed as well.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/i9.html
and the internet-archive: www.orgprints.org

The steamed band ready for sowing

Organic vegetables and green manure crops

The development of stockless organic cropping systems is held back by limited plant nutrient availability. Compared to farms with cattle, stockless farms grow less legume crops, have higher demand for manures for many crops, and have a larger export of plant nutrients with the crops sold from the farm. Vegetable crops are more expensive to grow than arable crops, and the risk of crop failure due to lack of available plant nutrients can make organic vegetable production a risky business. Therefore, organic vegetable production tends to be focused on a few vegetable species. We have obtained new knowledge on the effect of legume and non-legume green manures on factors such as plant diseases, pests, soil biology and on plant nutrients. We have found that green manures have a large effect on the soil fauna; the populations of earthworms and other animals were much larger while the green manures were grown, and for a substantial period afterwards. Short-term green manures undersown in cereals and left on the land during the autumn are also a valuable nutrient source.

Research is needed in order to increase the number of vegetable crop species, which can be grown successfully in organic farming. Through an intensive use of autumn grown green manure crops, we have attempted to increase the nutrient supply for the crops, to allow vegetable production to be made on stockless farms. We have studied the ability of green manure crops to improve the utilization of N, P, K and S in rotations and the effect of green manures on soil biology. We have also worked with simulation models to study the effect of green manures on nitrogen utilization and nitrogen leaching loss.

Growing different plant species, lead to different effects on "soil quality" for succeeding crops. The amount and depth distribution of available nutrients is changed, and also soil structure, soil microbiology and soil borne diseases are affected depending on the species grown. Valuable effects can be achieved by growing green manures but also by growing some of the common main crops. However, when growing green manures, the plant species can be chosen to optimize effects on the soil, whereas the main crops are obviously chosen mainly for economic reasons.

The main idea behind this project has been to use crop rotation planning actively to manage production problems. The main tool has been autumn grown green manure-crops, but we have also compared cropping systems and the significance of shorter crop sequences. Effects on crop nutrient supply, nitrate-leaching losses, on soil biology, plant diseases and pests have been studied.

Effect of green manure crops

Autumn grown green manure crops have significant effects on the soil fauna, and the populations are strongly increased where green manures are grown and also in the year following a green manure crop. The increased biological activity in the soil may have many effects. Especially, the increased populations of earthworms may contribute to an improved soil structure and the creation of bio pores in the soil.

Green manures did not show significant effects on insect pathogenic nematodes in the soil. With these animals, the main crops had a much larger effect, and there were very significant differences between organic and conventional neighbour farms. After crops of cabbage, carrots or peas, the population of insect pathogenic nematodes was high, but after a full year green manure it was quite low.

Chicory

Yellow kidney vetch

Different species of crucifers, which are grown as vegetable crops or as autumn green manures, have shown very different effects on the club root disease. Fodder radish was clearly less susceptible than the other species tested.

We have found that autumn green manures undersown in cereals may have a very good pre-crop effect. On sandy soils, we have found effect equivalent to 80-100 kg N/ha added as mineral fertilizer. Results from sandy loam soils indicate at least a similar effect. A range of legumes can be used with good results. The pre-crop effect of non-legume green manures is lower, but also very dependent on which species are grown, and how they are placed in the rotation. Normally, only grasses and legumes are used as under-sown green manures, but we have tested a number of alternative dicot species. We have identified chicory and woad as promising

Yellow kidney vetch

alternatives with very deep rooting and the ability to strongly reduce nitrogen-leaching losses.

Measurements of root growth

The experiments have shown large differences in rooting depth among vegetable crops and among green manures. Plants with deep rooting have been shown to be able to take up much N from soil layers between 100 cm and 250 cm depth. In some examples, the uptake from this layer was around 100 kg N/ha. Differences in rooting depth are important when planning a crop rotation. Placed correctly, the deep-rooted crops may strongly reduce leaching losses and improve N utilization within the rotation. On a coarse sandy soil, the studies showed much less rooting depth by the green manure crops.

Sulphur and phosphorus supply in organic rotations
Green manures can play an important role in the sulphur supply in organic rotations by making S available in the spring when the main crop needs it. Crucifer green manures are very effective at taking up S from the soil, preventing leaching losses and releasing S for the succeeding crop.

Studies have shown significant differences in P uptake and plant matter C/P ratio between green manure species. We tested whether green manures with a high P uptake could be

used to increase P availability on a low P soil. Such effects have been shown under tropical conditions, but we did not find them here. Maybe longer-term green manures can increase P availability, but the effect of short-term green manures grown only during autumn seems to be insignificant.

More vegetable crops for organic production

We have also worked on introduction of more types of vegetable crops in organic production. The studies have shown that most vegetable species may be grown successfully in organic farming. Even some of the "difficult" species such as cauliflower and broccoli have been produced with good yields and good quality, though the yield was somewhat lower than in comparable conventional crops.

Organic carrots and onions have also shown interesting results. The discarding due to pests and diseases tended to be lower in organically produced crops than in conventional crops. In carrots, the damage due to carrot root fly was lower in organic than in conventionally produced crops, and a similar result was found with mould and rot on onions after storage.

The yield levels were quite different among the vegetable crops though. Organic carrot crops gave the same yield as the conventional crops. With broccoli and cauliflower the yield was sometimes as high as in conventional production, but not always, and with onions the yield was always lowest in the organically produced crops.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/i10.html
and the internet-archive: www.orgprints.org

Production of organic grass and clover seed

In organic crop production, only organically produced seed is allowed. A prerequisite for optimal forage production is the availability of grasslands mixtures of grass and clover seed. Therefore, there is a need for organic seed of a variety of grass species and of clover. In general the organic production of grass seed is causing relatively small problems. Therefore, the focus of this project has been on the production of organic white clover seed, where the difficulties are the largest. Pests such as clover seed weevils and the lesser cloverleaf weevils are capable of reducing seed yield by 60-70%.

The lesser cloverleaf weevil does not appear as frequent as clover seed weevil, however the yield depression caused by the lesser clover-leaf weevil is much higher. Temperatures above 20°C are required before the clover seed weevil can migrate. An early defoliation of the clover canopy can decrease the frequency of clover seed weevils, but at the same time, the yield potential is being reduced. Mixed cropping of white clover, buckwheat and phacelia had no effect on the frequency of clover seed weevils, the lesser cloverleaf weevil and parasitoids.

The process of developing an organic grass and clover seed production is very advanced by the Danish seed growers and the Danish seed companies. In most grass species, sufficient amount of seed is available for the Danish home consumption, and in addition, seed for export is available. In organic production, seed yield is lower than in conventional production systems but still, organic grass seed production is not considered difficult. On the contrary, organic clover seed is still in request, and it appears that hardly any white clover seed production is carried out outside Denmark.

Hvidkløverfrø

White clover seed production is highly specialised production. To achieve a high reproductive development, the plant density should be open, however, this decreases the crop competitiveness against weeds. At a minimum, one week of dry whether is required to achieve a successful seed harvest. In addition, in organic production pests may reduce seed yield. These pests are clover seed weevils and the lesser cloverleaf weevil.

The objective of this project has been to identify the major obstacles for the development of organic production systems for organic seed and to develop management techniques to increase yield.

Within grass seed production the activities have been:

- Intercropping of perennial ryegrass seed and various green manure crops
- Development of management techniques for slow establishing grass species

Within clover seed production the activities have been:

- Establishment of white clover
- Registration of the migration of white clover seed weevils into the seed production fields
- Registration of the frequency of clover seed weevils in organic fields (Zeeland and Falster)
- Quantifying the yield reduction caused due to pests
- Combined forage and seed production
- Attracting parasitoids
- Demonstration trials

In addition, the seed yield potential of green manure crops and catch crops has been registered.

The migration of clover seed weevils

The theory is that by removal of the seed heads containing eggs of the clover seed weevils the seed yield reduction will be minimised. A prerequisite is to identify when the migration into white clover seed fields has ended and when the egg laying is terminated.

Yellow sticky traps have been mounted in 10 white clover fields situated on Zealand and Falster with special reference to estimate the time and temperature threshold for migration of the clover seed weevil into the clover crop. The results show that the weevils do not migrate if temperatures are below 20°C. This information can be used in a defoliation and burning strategy.

As earlier years, a damage threshold experiment has been carried out. The results show that an incidence in the area of 7 clover seed weevils per m^2 result in a yield reduction at 10 kg/ha.

The lesser cloverleaf weevil has been registered since 2002, and the yield reduction for this pest has been evaluated. As an average, there were 1-2 weevils per flower head. The yield reduction was 7 times higher due to the lesser cloverleaf weevil compared to the clover seed weevil.

Defoliation and burning

A number of organic farmers have burned the white clover seed production field in spring in order to test if this treatment would reduce pest damage. Information from these fields are utilised in this project.

At Research Centre Flakkebjerg, the treatment "burning" has been evaluated in a field trial since 2002, where burning is combined with defoliation. The results show that early defoliation in combination with burning gives the best result if the clover seed weevil is present. Number of weevils per flower head as an average is reduced from 7-8 to 2 when early defoliation is combined with burning. If defoliation is postponed 2 weeks, only 0.5 weevils are left and no significant difference between defoliation and defoliation + burning is found.

In 2002, white clover trial was established intercropping with buckwheat and tancy-leaf phacelia, plant species that are supposed to attract parasitoids. Number of clover seed weevil, the lesser cloverleaf weevil and parasitoids monitored in the trial show no significant difference between buckwheat/phacelia-plots and the control.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/i11.html
and the internet-archive: www.orgprints.org

Heads are examined prior to harvest for P. verrucosum contamination

Prevention of mycotoxin problems

Mycotoxins are natural compounds. They are produced by fungi and some constitute a well known hazard to humans and domestic animals. Relatively simple precautions concerning harvest, drying and storage can help preventing the proliferation of toxigenic fungi.

It is important to avoid soil contamination and reduce the amount of weed debris and immature kernels as much as possible in the harvested crop. Harvest and drying facilities should be cleaned properly. Furthermore, it is crucial to dry the grain quickly – especially if it has been harvested with moisture contents above 17% – as grain moisture is very important for mycotoxin production. Drum drying has proven very efficient for simultaneous fast grain drying and elimination of fungal propagules on the kernel surface without reducing the baking quality.

Mycotoxins are naturally occurring toxins. They are formed by fungi and some of them constitute a serious health threat to humans and domestic animals. Ochratoxin A (OTA) and trichothecenes are the most important mycotoxins in Danish grain. Danish surveillance reports of small grain cereals from 1986- 2000 showed that especially organically grown rye was sensitive to OTA. It is important to know how seed treatment, harvest, drying and storage practice in organic farming affect the risk of mycotoxin formation. The project had the following objectives:

- Studying the effect of different drying systems, especially drum drying
- Increasing our knowledge on the ecology of toxigenic fungi
- Pointing to farming practices that will reduce the abundance of toxigenic fungi

Comparison of different drying techniques

A new drum drying technique has been implemented for use in rye. The effect has been compared with other drying techniques regarding fungal occurrence in the grain and baking quality:

1. Drum drying (retention time 10.5 min.; grain temperature 62°C)
2. Continuous drying (drying air max. 65°C; grain temperature max. 45°C)
3. In-bin drying (optimal heat treatment)

Drum drying

4. In-bin drying (no heat treatment, insufficient aeration)

The experiments showed that drum drying was extremely efficient in reducing the number of fungal propagules on the grain – including the OTA forming species (*Penicillium verrucosum*). The effect of drum drying was much better than continuous drying and in-bin drying.

Seed quality and harvest practice

The project has elucidated the importance of seed quality and harvest practice on the occurrence of *Penicillium verrucosum* and its toxin – ochratoxin A (OTA). We conducted a field trial with grain that was naturally contaminated by *P. verrucosum*. The aim was to find out if contaminated seed can lead to growth and OTA production of the fungus in soil. We also investigated if contaminated seed increases the risk of contamination of the standing crop prior to harvest. The results did not confirm either.

Within the context of this subproject, a M.Sc. project addressed the problems with *P. verrucosum* in on-floor drying. The conclusions were that the fungus with great probability had been disseminated to the grain via insufficiently cleaned drying ducts. The results showed a significant increase in number of kernels contaminated by *P. verrucosum* during the period of drying and storage. Contamination was more heavy in rye than in oats and more so in the bottom layer of the batch close to the side ducts than in the upper layer.

In lab trials, we investigated how grain damage, grain moisture and temperature affected OTA formation and growth of *P. verrucosum*. Rye was inoculated with conidia of *P. verrucosum.* A part of the grain was mechanically damaged to simulate threshing damage. The purpose was to elucidate

Growth of P. verrucosum on rye

if damaged grain is more sensitive to fungal growth and OTA formation than undamaged grain. The experiments showed that grain moisture is more important for OTA-formation than temperature and apparently also more important than whether the grain is damaged or not.

Within the context of this subproject, we have cooperated with Bio-Centrum at the Technical University of Denmark on studies on genetic variability in P. verrucosum from different regions of Europe. The PREMYTOX project contributed with 87 isolates from two different farms. The results showed a surprisingly high variability in isolates from the same farm and this is important for further studies on the distribution of the species on a large scale (countries, regions) and on a small scale (seed, field, grain store).

Practical precautions to prevent problems with ochratoxin

Based on the results of the project, the following advice can be given:

- The OTA forming P. verrucosum is present in some soils and apparently more frequent in organically than conventionally cultivated soils. Therefore, soil contamination during harvest should be avoided.

- Field trials did not indicate P. verrucosum to be seed borne. The fungus is, however, often present in threshed grain. Harvest machinery should be cleaned properly and the combine harvester adjusted to minimize kernel damage.

- Quick drying is crucial, especially when the grain is harvested with moisture contents above 17%. Earlier studies indicated that problems with *P. verrucosum* were not necessarily linked to the organic farming system but rather to inappropriate drying conditions. Experiments with drum drying have shown that this technique is very efficient in reducing the number of fungal conidia on the grain – even without destroying the baking quality.

- The grain should be winnowed if it contains large amounts of impurities. This may result in "damp pockets" because the impurities often contain more moisture than the grain itself. If such pockets contain *P. verrucosum*, this may lead to OTA formation even at low temperatures.

- Driers, that are difficult to clean, may contaminate the grain heavily with conidia of *P. verrucosum* – especially if drying is slow. Large amounts of conidia will not always result in high contents of OTA, but it involves a risk if the environmental conditions become conducive to the germination, growth and toxin formation. It is therefore important that the drier is properly cleaned. Take care that the conidia are actually removed – not just whirled up. A powerful vacuum cleaner is advisable.

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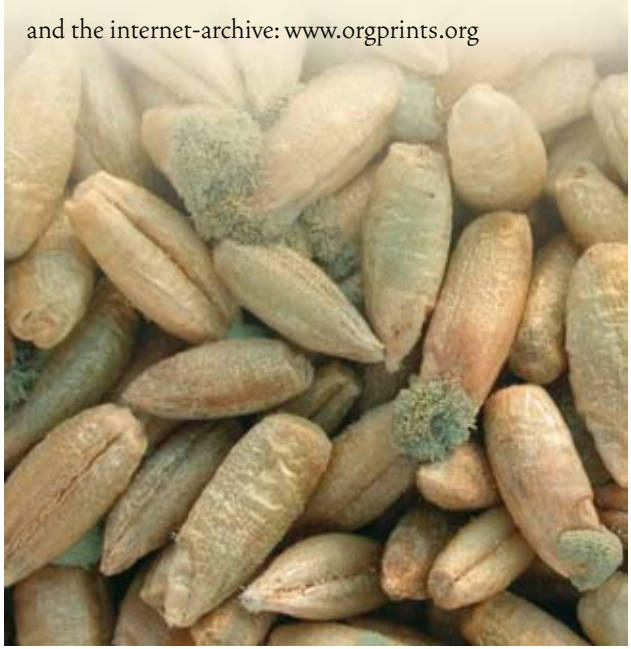
Publications and further information

See the project website:
www.darcof.dk/research/darcofii/i12.html
and the internet-archive: www.orgprints.org



Greenhouse gas emission and N- fixation in grass-clover pastures

Grass-clover pastures are important in organic dairy production systems. However, nitrogen fixation by clover combined with deposits of manure and urine from grazing animals may lead to significant emissions of harmful nitrogen compounds to the environment. The aim of this project was to provide new information on environmental consequences of organic production systems based on grass-clover pastures.

The emission of nitrous oxide from grass-clover amounted to less than 0,2% of the nitrogen fixation despite a significant rate of nitrogen cycling in the root zone. The results of the project suggest that the grass-clover pasture on the sandy loam emitted only small amounts of nitrous oxide. Compared to fertilized grasslands, grass-clover pastures may thus provide a strategy for maintaining soil nitrogen levels and potentially low nitrous oxide emissions.

Grass-clover pastures are important for organic dairy production, and the pastures are quite often grazed a significant part of the year. Fixation of atmospheric nitrogen (N) by the clover, in combination with animal deposits of dung and urine, however, may lead to increased emissions of harmful N compounds to the environment. Such emissions include gaseous losses of nitrous oxide (N_2O) and leaching losses of nitrate (NO_3-).

This project comprised experimental and modelling approaches to determine magnitude, regulation and relationship between N_2O-emission and N-fixation in grass-clover under varying grazing intensities and soil conditions. The aim of the project was to provide new information on environmental consequences of organic production systems based on grass-clover pastures.

Image analyses of urine patches in grass-clover

Emissions of nitrous oxide

One experiment showed that the N_2O emissions from soil without urine deposits mounted to 0,2 - 2 g N per ha per day independent of pasture age. The contribution of recently fixed N to N_2O formation was negligible.

The daily mineralization of N in the top 15 cm's was between 61 and 123 kg N per ha, which cumulates to a seasonal (April-October) N-mineralization of 15 tons. Most of this N is immediately taken up by plants and microorganisms, and approximately 10% is transformed to nitrate by the nitrification process. This process may produce N_2O. The experiments indicated that 0,05 % of the N transformed by nitrification was emitted as N_2O. This ratio, however, was very variable but with no clear relationship to environmental conditions driven e.g. by seasonality. It needs to be emphasized that the investigated grass-clover was grown on a relatively sandy soil. More clayey conditions could lead to higher N_2O emissions.

Gathering N_2O from grass-clover

In another experiment, we investigated the turnover of both N and carbon (C) in urine patches. Previous works have showed that urine patches are significant sources for N_2O. One hypothesis is that roots damaged by scorching may leach C compounds into the soil and thereby increase formation of N_2O. This experiment showed a significant cycling of N and C in urine patches, but no evidence of increased availability of plant derived C. The total loss of N_2O contributed to 0,3 % of urine N, which was less than expected.

Nitrogen fixation

The fixation of atmospheric N was dependent on the age of the grass-clover. Total plant production in a 2nd year grass-clover exceeded that in 1st and 8th year grass-clover fields. N fixation as well as fraction of clover in the 8th year field was less than in the 1st and 2nd year fields throughout the season. Total N fixation in harvested biomass in 1st, 2nd and 8th year fields, respectively, amounted to 59, 79 and 49 kg N per ha.

The investigations also suggest that the formation of stolons and roots under clover takes place mainly during the 1st production year and is not increased further in succeeding production years. In contrast, the root biomass under the grass increases with pasture age. As a consequence of this, the contribution of N fixation in stolons and roots to total N fixation in perennial grass-clover systems should only be accounted for in the 1st production year.

Setup of greenhouse and field experiments was done in order to investigate the impact of grazing, simulated by frequent cuttings on the N fixation. These experiments showed that aboveground as well as belowground biomass was reduced by 20 – 30% compared to a normal cutting frequency under non-grazed conditions.

Controlled urine depsition for measuring N_2O emissions

Nitrous oxide emissions as influenced by urine deposition

Field monitoring focused on methods for describing the spatial distribution of grazing impacts (urine deposition, compaction), as these factors can be influenced by management.

Sward growth is stimulated by the deposition of N in urine, and image analysis of pictures taken at 13 m height, which described a section of the pasture, showed a high intensity of urine patches in the area around the water source. Due to the large N deposition, there may be an elevated potential for N_2O emission from this part of the pasture.

The relationship between urine composition and N_2O emission was examined after rotational grazing and in controlled experiments with simulation of urine deposition under field or laboratory conditions. In the field, the results showed spatially variable, but temporally stable emissions of N_2O where soil conditions were appropriate. We found no evidence for an effect of soil compaction on N_2O emission in the sandy loam soil, whereas high N_2O emissions coincided with elevated N concentrations in the soil.

The investigations of urine turnover in the soil were coordinated with activities within an EU project, which made it possible to expand the experiments on regulation of N_2O emissions. A laboratory study with urea deposition

to pasture soil without vegetation, showed that C is released from soil pools (including the microbial biomass). Nitrous oxide emission appeared to be proportional to the amount of N deposited.

Across a grazing season, an average increase in soil compaction of around 10% was observed, but as stated above, we did not find evidence for an effect of compaction on nitrous oxide emission.

Modelling nitrous oxide emissions

In order to further develop and validate a model for the simulation of N_2O emissions from pastures, experimental monitoring data were obtained from pastures in Finland, UK and Denmark. The model was improved to give at better agreement between measured and simulated levels of N_2O emission. Furthermore, the revised model responds to N amendments in a way that is generally in good accordance with literature values.
Model calculations demonstrated a significantly higher N_2O emission from more clayey soils compared to sandy soils, which is due to the differences in soil aeration. The emission of N_2O is stimulated by N fertilization, mainly due to the higher mineral N availability to soil microorganisms. The model also suggested that the N_2O emission factor, i.e. the proportion of N amendment that is converted to N_2O, increases with increasing N inputs. The increase in N_2O in response to fertilization was particularly pronounced for clay soils and in grazed pastures.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/i13.html
and the internet-archive: www.orgprints.org

Control of scab in organic apples

Apple scab is the most serious of the apple diseases, both in organic and conventional apple production. In organic apple production effective methods of preventing the disease are scarce. There is therefore an urgent need for alternative control methods to be developed. The primary aim of the project is to identify potential control measures against scab that do not conflict with the principles of organic farming.

Several different remedies against apple scab such as plant extracts, different oils or bio-control agents have been tested in the laboratory, in a growth chamber and in an organic orchard. Several of the measures were of potential interest, but if they are to be applied in practice, they will require further testing for toxicity and effectiveness. Large parts of the project are continued in the EU project "Replacement of Copper Fungicides in Organic Production of Grapevine and Apple in Europe" (REPCO).

Apple scab

Apple scab is caused by the *Venturia inaequalis* fungus, which causes considerable production losses and problems with the quality of organic apples both in Denmark and abroad. The fungus overwinters on fallen leaves from where it produces fresh spores in spring that spread on the wind and settle on newly formed leaves, particularly in connection with precipitation. The spores grow on the leaf surface and cause leaf infections. This produces many new spores that subsequently can spread and cause new infections in leaves and fruit.

Conventional apple production uses large quantities of fungicide several times during the growing season to eradicate apple scab. Only sulphur spray is allowed in organic apple production in Denmark. Other European countries still allow the use of the more effective lime-sulphur and copper-based remedies. As sulphur sprays are not terribly effective and the use of copper as a pesticide will be phased out from 2006, alternative remedies against apple scab are needed.

This project has primarily involved the identification of candidate remedies in apple scab control in organic farming. A number of different plant extracts, essential oils and bio-control agents were tested in the laboratory, growth chambers and greenhouse for their effect on the fungus. Promising alternative remedies underwent further experiments to find out how they work, of which some were selected to be tested in organic orchards including studies of treatment effects on the metabolism of apples.

Apple seedling with initial symptoms of scab on leaves

Screening of alternative remedies

Potential remedies were collected and tested for their effectiveness against apple scab in the laboratory, growth chamber and greenhouse. The materials included plant extracts (raw and processed), essential oils, bio-control agents and other remedies, including potential resistance inducers. Standardized experiment protocols were developed and the materials tested. Water was used as control treatment and sulphur spray as reference treatment. A total of 59 materials were screened, of which 26 were tested for their effect on the germination of fungal spores. During the first 1½ project years (2002-3) the screenings were performed on potted apple trees in greenhouses at The Royal Veterinary and Agricultural University (KVL). During the latter part of the project (2003-4) the screenings were continued on apple seedlings in growth chambers at KVL.

Two materials were chosen for more in-depth histopathological studies of their potential as resistance inducers and for molecular studies of host plant defense responses.

Three promising materials (two plant extracts and one resistance inducer) were tested in an orchard at Danish Institute of Agricultural Sciences, DK-Aarslev during the spring 2003, and seven materials (including two of the materials tested in 2003) were tested during the spring 2004.

Molecular studies of control mechanisms

Where a compound was observed to have an effect on the control of apple scab in the growth chamber or greenhouse screenings, the mechanism behind the control was investigated under microscope. The mechanism may be

in preventing the attachment of spores to the leaf surface, or in the eradication or inhibition of the germination and growth of spores thus preventing its establishment in plant tissue. The plants' own defense mechanisms can also be triggered by indirect effects from other plants, oils, salts and micro-organisms. This is termed induced resistance and the materials used to promote these effects are called resistance inducers.

The course of an infection was followed by treating some leaves with water (control treatment) and some leaves with the commercial product, ASM, which is a known resistance inducer and comparing with a plant extract, E73. From subsequent samples of *V. inaequalis* spores, it would appear that ASM works by induced resistance. In contrast to ASM and water treatments, E73 had a marked fungicidal effect on the germination of spores and an inhibitive effect on the development of spores both before and after spore penetration. However, this does not rule out the involvement of induced resistance for this plant extract. Molecular examinations of the activation of defense mechanisms in induced apple plants were therefore started.

Counting leaf infections in an organic fruit orchard

Testing of control remedies in organic fruit orchards

In 2003 and 2004 new potential organic farming-approved control compounds were tested against apple scab on leaves and fruit in the primary infection periods. Testing was performed either on 'Jonagold' apples or on the 'Delorina' variety in combination with different cover crop treatments in order to establish different fertilizer levels for an optimal tree growth and yield. The following products were tested: E52, C-pro (extract of grape fruit seeds), O5, Terre Biosa (also known as Effective Microorganisms), E63, E73, BionTM (Acibenzolar-S-methyl and Ivy extract (*Hedera helix*). Sulphur or copper oxychloride were used as control treatments. Under the conditions of the trials, none of the new candidate fungicides tested in 2003 and 2004 gave an acceptable level of scab control. Sulphur, in combination with a soil treatment that reduced the level of nitrogen available to the trees, gave the best yield of apples, with a low incidence of apple scab. The results show that more work is needed in order to find effective alternative fungicides for control of scab in organic apple orchards.

The future

The aim of the project was to identify potential alternative remedies to fight apple scab in organic farming. The work with the identification and development of these alternative remedies continues in the EU project "Replacement of Copper Fungicides in Organic Production of Grapevine and Apple in Europe" (REPCO).

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/i14.html; the
EU project Replacement of Copper Fungicides in
Organic Production of Grapevine and Apple in Europe
(REPCO): www.rep-co.nl
and the internet-archive: www.orgprints.org

Nitrate leaching from dairy farming

In grasslands, there are accumulated huge amounts of nitrogen (N), which may be difficult to utilize efficiently. This is especially the case on more sandy soils. Therefore, the effects of different management options were investigated with the purpose of optimising nutrient utilisation and minimising nitrate leaching.

The results indicate that proper management is extremely important to avoid considerable nitrate leaching. But even on course sandy soil, it is possible to limit leaching to a minimum.

Improved utilisation of grassland nitrogen

In grassland grazed by dairy cows, there is accumulated huge amounts of nitrogen, which may be difficult to utilise efficiently following ploughing. Good management practises like spring ploughing of grassland, reduced fertiliser input and use of catch crops improve the utilisation. But even when this practise is fully implemented, farming systems with grazing cows have a considerable N-surplus.

Furthermore, it is a remaining question, whether the mentioned management practices are fully efficient also on course sandy soils. Large volumes of nitrate leaching have been observed from course sand when cultivating grassland despite the fact that best management practices seemed fulfilled. This may be caused by release of nitrogen exceeding the capacity of the catch crop at this specific point in time. The situation may occur when older grasslands with continuous grazing are ploughed or the catch crops are poorly established.

As the dairy farm size increases, an increasing number of farms are not able to graze all fields in the crop rotation. On large farms, grazing on fields distant to farm buildings is difficult or practically impossible. Especially, on farms with automatic milking systems. On these farms, there is a high frequency of grasslands with large N-surpluses in the rotation near the farm. Furthest away from the farm is a cash-crop rotation with low N-surplus.

In nitrate vulnerable zones with agricultural production, organic dairy farming may present an opportunity to reduce nitrate leaching if grassland N is efficiently utilised. The objective of the project was to determine the importance of the grassland composition and frequency in the crop rotation for residual effects on yield and nitrate leaching during grazing and following ploughing in order to:

- increase the total N use efficiency of the crop rotation and reduce N leaching losses from dairy crop rotations
- suggest specific changes to management and rotation, that may be carried out in e.g. nitrate vulnerable zones within the short term, and
- establish a scientific sound basis for giving advise on these matters in both organic and conventional farming

Use the pre-crop effects of grassland

At Foulum, three crop rotations have been built up with different frequency of grazed grassland including both unfertilised grass-clover and fertilised pure ryegrass. During 2002-2004 the crop rotations were similar but they differed over a longer period by having 25, 38 and 75% grassland in the crop rotation. In other words, we investigated the long-term effect of grassland frequency. In 2005, all grasslands were ploughed and the residual effect and nitrate leaching was determined following ploughing.

The results showed that there was no effect of fertiliser application in previous years or the type of grassland (grass-clover or ryegrass). However, the frequency of grassland in the crop rotation affected yields in the cereal crop following ploughing. In the crop rotation with 75% grassland, 4,2 t barley grain per hectare was harvested since 1997 compared to only 3,2 t in crop rotations with 25 and 38% grassland. These yields were without fertiliser application, thus entirely based on the residual effect of the grasslands.

Catch crops important

It is well known that the risk of nitrate leaching is huge on coarse sandy soils. To investigate this in relation to large dairy farms in 2003, we ploughed out a grazed 5-yr-old pasture close to the farm and a 2-yr-old pasture mainly used for silage cuts further away from the farm. Following ploughing of grassland different cropping situations with spring barley was investigated, varying from well-established Italian ryegrass following early harvest of barley (green) to no catch crop and mechanical weed control in the autumn. The catch crops had enormous effect on nitrate leaching. With a well-established catch crop leaching, losses were modest mostly below 10 kg N per hectare. Contrary, bare soil and mechanical weed control caused leaching that in some cases exceeded 200 kg N per hectare.

The experiment most dramatically illustrated the importance of good management practices for the reduction of nitrate leaching. Even on the coarse sandy soil, it was possible with a well-established catch crop to keep leaching losses at a minimum.

In the experiment, leaching of dissolved organic N was furthermore determined, which until now have had little attention. The results showed that leaching of organic N in this type of crop rotation could not be neglected.

Relevant for future dairy farming

The results from the project are relevant for planning organic crop rotations especially in nitrate vulnerable zones. The development towards a larger number of cows per farm effects the disposition rights of the farmer regarding grazing possibilities in the crop rotation. The grazing of distant fields becomes difficult and the result is a crop rotation near the farm with high grassland frequency while away from the farm, the crop rotation is dominated by cash crops. It is important that the farmers are aware of the consequences for N utilisation and the environment.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/i15.html
and the internet-archive: www.orgprints.org

Ground water protection and organic farming systems

In Denmark, it is of high priority that we can drink our ground water without any treatment. This will only be possible through some kind of management. Areas with drinking water interests are appointed and afterwards, areas, that are especially vulnerable to leaching of pesticides and nitrate, can be regulated. Organic farming in such areas is interesting because no pesticides are used.

Further, it was possible to come up with sound organic crop rotations that can reduce nitrate leaching from the root zone considerably. The effect in the drinking water aquifers on loamy soils will only be in the long run. The hypothesis about less nitrate leaching due to an effect on the hydraulic properties and due to denitrification could not be confirmed.

In Denmark, the public gives high priority being able to use untreated ground water for drinking. There is a growing understanding that clean ground water can only be maintained through active means. A way of regulating land use in vulnerable areas could be to use organic farming. Pesticide use will then stop. The leaching of nitrate will depend on the type of organic cropping system used and that is the focus of this study.

Our hypothesis is that some of the management steps that characterise organic farming systems can change both the quantity and the quality of the ground water compared with conventional farming. The idea is to focus on the aspects of organic farming systems that presumably will affect the

ground water. The total effect of the different management steps on ground water can only be evaluated by the use of a model that integrates the effects from the farming system. The following questions were investigated:

- How are the hydraulic parameters affected by organic farming?
- Will a higher amount of dissolved organic carbon leached from the organic farming systems result in a decrease in the leaching of nitrate due to the higher denitrification?

We suggest systems of organic farming that are more able to reduce nitrate leaching and which will be tested in model scenarios to calculate the leaching from the vadose zone. Further, some of the scenarios will be modelled for a catchment area to see whether the effects will persist in ground water at the regional level.

Hydraulic properties

We especially need knowledge about how the hydraulic parameters are affected by the farming system. We have identified three management tools that we think would be of particular importance for the hydraulic properties of soils: the level of application of farmyard manure, the effect of crop rotation and catch crops, and on-land ploughing.

The hydraulic properties were only insignificantly affected by the organic management steps, which were investigated. No

difference could be detected between long-term applications of animal manure versus synthetic fertilizer, but there was an effect of the general fertilizer level.

The effects of crop rotations were small. The hydraulic conductivity was smaller in the diversified crop rotation with catch crops probably due to more roots in the macro pores.

Leaching of dissolved organic carbon

Different aspects of organic farming systems, as for example the widespread use of grass-clover and animal manure, is assumed to have a positive impact on groundwater quality. The reason for this assumption is that organic farming hereby introduces larger amounts of organic matter to the soil, which increase the denitrification and consequently reduce the leaching of nitrogen. We have tried to verify this assumption under field conditions on two sandy soils by measuring the leaching of dissolved organic carbon and nitrogen under cereal crops after the cultivation of grass-clovers.

The use of catch crops after the cereal crops reduced the leaching of nitrogen significantly with a reduction up to 95% when the cereals were harvested early for silage allowing the catch crop to be fully developed before autumn and winter. The leaching of nitrate constituted from 50 to 90% of the total nitrogen leaching, and the leaching of dissolved organic N (DON) was up to 25 kg N per ha per year in a treatment where the cereal was harvested at maturity and without catch crops.

Does DON contribute to the transformation processes in the soil?

Next, the question is whether leaching of DON should be considered as an extra component of leaching or if DON and dissolved organic C (DOC) contribute to an increased denitrification and thereby is reducing the leaching? Laboratory studies showed that addition of C as energy source for denitrifying bacteria only had a significant effect

on the denitrification at high soil water contents, i.e., when the water content approached 80% of saturation. So in spite of the relatively large amounts of DOC, which was leached (up to 160 kg C per ha per year), it is not assumed to contribute to an increased denitrification until it eventually reaches the vadoze zone of the soil profile, i.e., the temporarily water saturated zone.

Modelling of nitrate leaching

A sensitivity analysis for duration of grass-clover, time of soil ploughing and catch crops showed that increasing durations of grass-clover increase the N-leaching after soil ploughing and that undersown catch crops can reduce the NO_3 leaching heavily.

Organic crop rotation systems were designed for the different farm types in a groundwater protection area "Søndersø" on Funen. The amount of inorganic nitrate leached from the root zone is considerably lower in the groundwater protection area after conversion to organic farming, 29 kg N/ha compared to 70 kg N/ha in average before the conversion. Around 50 % of the nitrate leaving the root zone in the groundwater protection area is reduced in the redox zone. This happens in both scenarios, and in the respective areas, there is no effect of the land use change. Further, the mixing with older groundwater will delay the effect of the conversion.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/i16.html
and the internet-archive: www.orgprints.org

Organic milk production

An increased focus on self-supply with feed is expected in future organic dairy production systems. As a consequence hereof and as the yield potential clearly is highest in the typical roughage crops (grass, maize and whole seed) under Danish cultivation conditions, the feed ration is expected increasingly to be based on roughage and less on protein rich and concentrated crops such as peas, rape, lupines and grain to maturity. Scenario analyses have shown that the roughage quality is one of the most important factors on a farm self-sufficient with feed, as it has an important impact on the feed intake, feed utilization and milk yield as well as on the financial situation of the farm. Production trials have shown that as long as the cows are in good condition and the roughage digestibility is high, a reduced total energy intake, due to a higher proportion of roughage, will not increase the risk of ketosis. Production trials on private study farms showed that the type of supplementary feed, barley, rapeseed, rape cake or green pellets, affects the milk yield of the cow only slightly when the cows are fed with roughage of high digestibility ad libitum.

There is a need for knowledge of how to develop the dairy farm in a way to ensure a high degree of self-supply of feed and manure without losing profitability of the farm and so that the feeding meets the demands of the animals and contributes to the quality of the products. Consequently, it is imperative to elucidate the biological effectiveness of such systems as well as critical partial elements of them.

The basic idea of this project was to investigate the possibilities and consequences of increasing the amount of roughage in the feed ration to the dairy cow. Therefore, we have carried out activities concerning the quality of the roughage, amount and types of supplementary feed, feeding level and a change of the herd structure by means of a prolonged calving interval. In addition to this we have tried to quantify the results in relation to productivity, finance and use of resources, by modelling based on a farm self-supplied with feed and manure.

Roughage quality – a very important factor

Scenario analyses showed that the roughage quality is one of the most important factors on a farm self-sufficient with feed, as it has an important impact on intake, feed utilization and milk yield of the cow as well as on the financial return at farm level. If, e.g. the digestibility of clover-grass silage can be increased by 2.5 percentage-points, the economic result to the farmer can be increased by approx. 30%. If a significant part of the ration consists of whole crop silage, the roughage quality may be enhanced by increasing the

amount of clover-grass silage while reducing the amount of whole crop silage. Due to the fact, that both feed intake and milk yield increase per cow, a most positive effect on the financial situation of the farm is achieved. However, the model calculations also showed that the N surplus per ha rises in this system and thus increases the risk of N leaching. Consequently, the traditional re-ploughing of the clover-grass after two or three years lay should be critically scrutinized.

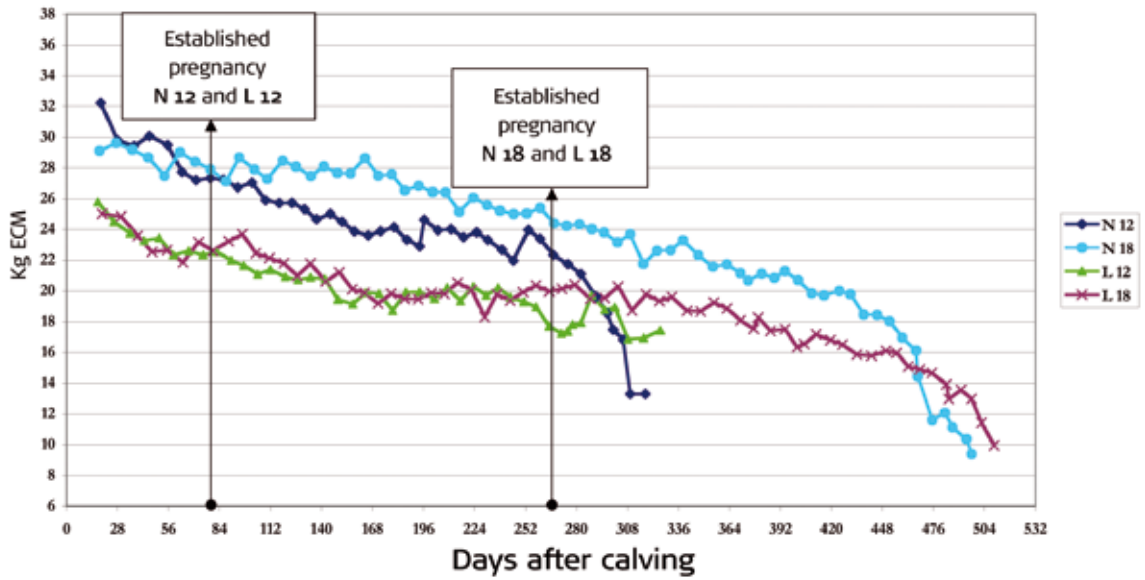
The share of roughage should depend on the roughage quality

By reducing the level of supplementary feed per cow, the share of roughage in the ration is increased. A higher proportion of forage crop follows this, which often is higher in yield than cereals and pulses. On a farm totally based on home grown feed, this will have a positive effect on the production at farm level. However, this is only true when the roughage is highly digestible and if, in the crop rotation, it is possible to increase the share of clover-grass.

A reduced fodder level does not increase the risk of ketosis

In a production trial, some of the cows were only given 1.1 FU rape cake for supplementary feed. Only few cows – despite the low energy supply – showed some signs of being physiologically unbalanced (indicated by a low glucose concentration), and the mobilization was also low (indicated by a low NEFA concentration). These favourable results are primarily explained by the fact that the animals were in an ideal body condition at calving and that the quality of the ad libitum feed was high. Moreover, compared to grain (4.3 SFU) supplement of rape seed/grain (3.7 SFU) had no negative effect on the physiological status of the cows.

Figure: A prolonged calving interval may increase the yield. (Two feedinglevels, normal (N) and low (L) and two calvingintervals, 12 and 18 months)



The yield of the field is decisive for the best supplementary feed

Production trials on private study farms showed that the type of supplementary feed, barley, rapeseed, rape cake or green pellets, affects the milk yield of the cow only slightly when the cows are fed with roughage of high digestibility ad libitum. On a self-sufficient farm, supplementary feed can for financial reasons thus be chosen according to the productivity of the crops. The financial return of the farm is more dependent on the productivity in the field than on minor differences in annual milk yield per cow caused by different types of supplementary feed. When choosing supplementary feed, it is nevertheless still important to focus on the influence of the feed ration on the cow's health and especially on the composition of the milk.

A long-term experiment carried out at Rugballegaard, which is an organic research station, showed that a prolongation of the lactation period and thus the calving interval from 12 to 18 months gives a possibility of an increased share of roughage in the ration. This is due to the fact that there are relatively fewer days in early lactation, where the proportion of concentrated feed is highest. It also results in fewer days dry per calving, as number of days dry per lactation remains the same. In the experiment a prolongation of calving interval had the result that the lactation yield increased from 7,656 to 11,516 kg ECM, or an increase of 371 kg ECM annually with prolonged calving interval compared to a traditional calving interval. Reproduction results did not change. Based on these differences in yield and on share of roughage the profit calculated for a strategy with prolonged calving interval was higher than that of a system with the traditional calving interval. A lower number of young stocks per cow explain around half of the improved financial results, while the rest of the improved economy among other things is due to fewer feeding days of dry cows and higher proportion of roughage.

Leader-follower system for grazing purposes may enhance the utilization

In order to take into consideration both the demand for a high grass intake as well as a high utilization of the potential herbage growth, a new grazing system was investigated. The grazing system is based on rotation grazing where the cows are grazing the paddock for two days followed by two days of grazing with heifers and dry cows. The leaders (the lactating

cows) thus graze the best part of the herbage whereas the followers, the heifers and dry cows, cleaned up – not leaving any old grass-clover behind. Compared to traditional ration grazing, this system can increase the daily dry matter intake of the cows by up to 10% dry matter per day. When tested, the system worked satisfactorily, which was seen, among other things, from the fact that the followers grazed the paddock tight together with a high daily live weight gain and the fact that only one trimming of the paddock was needed per season.

Grazing enhances the CLA content of the milk

Several investigations have shown a positive effect on the risk of cancer of feed with high level of CLA. Analyses of milk collected on private study farms showed that differences in the feeding of cows is the cause of by far the greatest part of the variation in the CLA content in milk. The CLA content in milk fat may be made 3 to 5 times higher by altering the composition of the feed ration to the cows. The CLA content is greater in the summer during grazing than in the winter when fed silage. The reason for this is both that fresh grass has a high content of unsaturated fat and that fresh grass influences the rumen environment that favours the formation of t-vaccenic acid, which is then transformed to CLA in the udder. No systematic differences in the CLA content were found between milk from organic and conventional herds due to the fact that the feed ration was quite similar on the farm investigated. It is in general expected that milk from organic herds primarily fed with fresh clover-grass might have a higher CLA content than milk from conventional herd fed with higher amounts of silage.

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Publications and further information
See the project website:
www.darcof.dk/research/darcofii/ii1.html
and the internet-archive: www.orgprints.org

The quality of organic milk and cheese

An organic production of milk is based on the desire to primarily use locally produced crops for animal feed. This involves the inclusion of large quantities of legumes such as clover, lupin, broad beans and peas in the feed. The effect of these crops on different quality parameters in milk and cheese were investigated. A number of other parameters in the production of quality cheese from unpasteurised milk were also investigated.

The results show that although organic milk production generally uses less synthetic vitamin E, the vitamin E content is higher in organic milk than in conventional milk. The content of carotenoids, which act as antioxidants and form a number of significant aroma compounds is similarly higher in organic milk.

Organic milk quality

Future regulations for organic production of milk stipulate that all feed must be organically produced, and that the cow can only be fed natural vitamins and antioxidants. The feed is expected to mainly comprise locally produced crops, primarily grass/clover, legumes and cereals.

The objective of the investigations was to assess the effect of feed composition on the milk content of vitamins, antioxidants and the fatty acid composition of milk. These factors affect the taste shelf life and nutritional quality of milk.

Increased vitamin E and antioxidant content

From May 2003 until February 2004 milk samples were taken from organic and conventional herds and analysed for potential vitamin and antioxidant content, together with a number of liposoluble vitamins and the composition of lipids.

The investigation focused particularly on vitamin E levels (α-tocopherol) as vitamin E extends the shelf life of milk through its function as an antioxidant. Vitamin E is a natural constituent of plants and plant-based products in the animal feed, but the vitamin is also synthetically produced. The synthetic production of vitamin E involves the formation of eight different forms (stereo isomers), of which only one is identical to the naturally occurring form.

Milk analyses show that in 7 out of 10 samples, organic milk contained significantly more vitamin E than conventional milk (Figure 1). The content of synthetic vitamin E was also lower in organic milk (6.2 - 13.5%) than in conventional milk (15.8 - 24.7%) (Figure 2).

The results indicate that in an organic production, less synthetic vitamin E is generally added to the milk. But the vitamin E content, nevertheless, manages to be higher in organic milk. The results also indicate that from a milk quality point of view there is no basis for an extension of the dispensation to use synthetic vitamin E in organic milk production.

The other group of compounds of interest were the carotenoids that function as antioxidants, but also form a number of important aromatics in the milk. Analyses show that the level of carotenoids was higher in organic milk and the level of the beta-carotene compound was 2-3 times higher in organic milk than in conventional milk.

The experiments also showed no difference in the fatty acid composition of the milk as the two types of milk contained equal quantities of the conjugated linoleic acids (CLA).

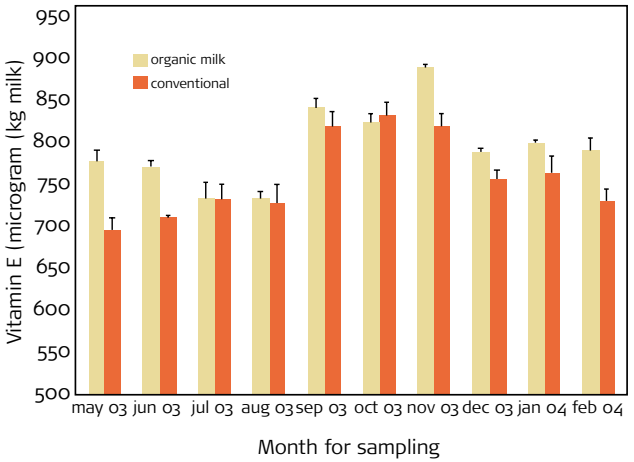

Figure 1: Vitamin E content in conventional and organic milk

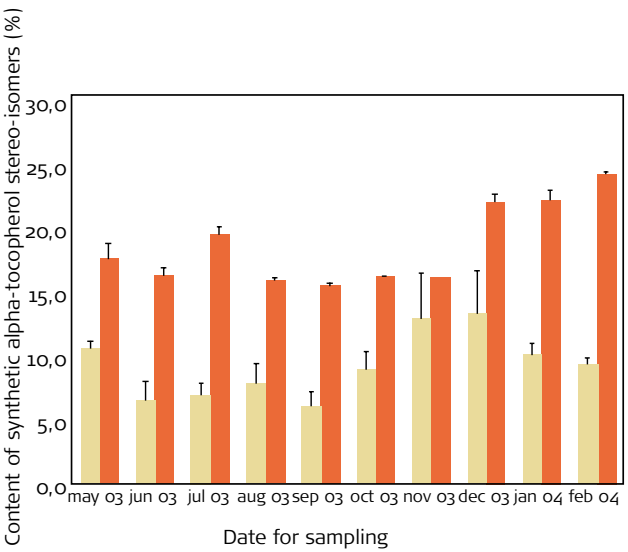

Figure 2: Content of synthetic stereo-isomers of vitamin E in conventional and organic milk

Phyto-oestrogens

As previously mentioned, the use of legumes such as clover, lupin, broad beans and peas used in the feed for organic dairy cows is on the increase. Legumes, but also cereals, nuts

and vegetables, have an inherently high content of plant oestrogens – also called phyto-oestrogens. Phyto-oestrogens are the common denomination for the large group of compounds with oestrogen-like effects. A number of investigations indicate that phyto-oestrogens can have a preventive effect on the development of a number of lifestyle diseases.

The content of different phyto-oestrogens in milk and animal feed in different organic dairy herds has been investigated. Milk samples were collected from a large number of cows to examine the variation in the phyto-oestrogen content in relation to season and feeding practices. A number of feed samples were also collected in connection with the milk sampling and blood samples were taken from a number of cows for the preparation of a serum.

The content of genistein (an isoflavonoid) and enterolactone (a lignan) have so far been analysed in serum from 11 organic dairy cows. The milk samples were taken from housed cows and from cows on pasture. The serum has been analysed by Time Resolved Fluorometric Immuno Assay (TR-FIA) using commercial kits. Preliminary results show concentrations of enterolactone of between 300 and 1500 nmol/l and concentrations of genistein of between 5 and 50 nmol/l. Enterolactone concentrations were highest from cows on pasture, while genistein concentrations were lowest from cows on pasture.

Quality of cheese produced from raw milk

The production of organic cheese is mainly based on the production of a number of cheeses that are also produced from conventional milk. If the market share of organic cheese is to be increased, it is important that they are of a quality that justifies a higher price compared with conventionally produced cheese. It is often said that cheeses based on raw milk can achieve a richer sensory quality than conventional products. This requires documentation of the cheeses having a different flavour than pasteurised cheeses.

Using creamy cheeses with orange-red rinds, which are based on respectively un-pasteurised and pasteurised milk from an organic on-farm dairy, methods of evaluating flavour

components and functional qualities of cheeses have been developed. This has included textural analyses, flavour analyses based on a high vacuum distillation, peptide profiling and the use of an electronic nose.

Quality control of cheeses made from un-pasteurised milk

Denmark has a very restrictive policy for the production of cheeses made from un-pasteurised milk, due to the potential problems with food safety. In order in future to be able to assess the microbiological safety of un-pasteurised cheeses, it is necessary to have a number of control and monitoring points at different stages in the production process.

The project has evaluated the prospects of introducing guidelines for the safe and optimal production of cheeses using a self-regulatory control programme. The procedure – a so-called generic Hazard Analysis Critical Control Point (HACCP) – has been tested on an organic farm.

The results of the microbiological analyses show no clear systematic differences between cheeses made from un-pasteurised or pasteurised milk. It is, however, not thought likely that the programme will prevent the presence of pathogens or other health risks.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/ii2.html
and the internet-archive: www.orgprints.org

The chicory plant

Quality of organic beef and pork

Organic production of meat products in Denmark includes primarily beef and pork. The present market share of beef and pork in relation to the total national production is about 0.5% and 2.1%, respectively. The demand for high quality organic meat is limited, and there is a strong need for better marketing of products, more focus on physical and sensory qualities and more cost-efficient production methods, still in accordance with the principles of organic farming.

Preliminary results have indicated that organic pork has a higher content of poly-unsaturated fatty acids compared to conventionally produced pork. This is probably related to different protein sources in the feed and extensive feeding of roughage. It was possible to change the eating quality of pork in a very favourable direction by feeding the pigs roots of chicory. Furthermore, pork from pigs fed chicory has shown little tendency to go rancid. The use of alternative crops for improvement of meat and eating quality offers new and promising perspectives for the organic meat production.

The demand for high quality organic beef and pork is increasing, although still limited. Similarly, environmentally safe and ethical acceptable production methods are increasingly demanded by the critical consumer. For these reasons, it is important to formulate new strategies for organic meat production.

The major objective of the project has been to develop and document animal welfare friendly and economically viable production systems for high quality beef and pork. Major emphasis has been on steer production with regard to improved health and welfare, product quality and to increase the nature quality of marginal lands (e.g. species diversity) by means of extensive grazing.

The use of bioactive forages and crops for ruminants and pigs, aiming at improved product quality and better health by preventing parasitic infections, was also investigated extensively. The studies showed that several crops may affect

the quality of the meat product and the parasitic status of animals during grazing.

The studies were performed on private farms, on grasslands with cattle and sheep and under experimental, housed conditions with pigs and cattle. The studies included use of chicory roots, which was expected to improve the health and eating quality of organic meat from steers and pigs.

Organic production of steers based on dairy breeds

A questionnaire study indicated that only 10-15% of bull calves from organic dairy farms were raised and finally slaughtered as organic produced. The remainder of bull calves was either sold for conventional production or euthanized soon after birth (primarily Jersey calves).

An expected low economic return rate was the major impediment for organic rearing of bull calves. Our economic calculations clearly confirmed that under the present conditions, the net return may indeed be low or uncertain.

The interest for veal and beef production is, however, increasing, and there is a need for reliable evidence-based knowledge of production characteristics and optimal feeding strategies. A relevant strategy for organic beef production based on dairy breeds is the production of steers (castrated bull calves). Steers need two summer seasons on pasture in order to reach target weight. Mathematical modelling has indicated that high daily weight gains in the second season on pasture is crucial for economic sustainability. An intensive finishing period is usually recommended but is, in fact, not needed if the growth rate is high. Grazing with steers may also increase the biodiversity of marginal

grasslands which is an important contribution to the fulfilment of the goals of organic farming.

Bioactive crops have effect on parasites and boar taint

Our studies on lambs and pigs indicate that certain crops (e.g. chicory) may have positive effects on parasite infection levels and/or meat quality at slaughter. These crops for feeding are called bioactive forages because the effects seem to be associated with the contents of particular bioactive compounds in the plants. The use of bioactive crops as well as other relevant plants within organic production systems is only poorly exploited.

The results of feeding fatteners with bioactive forages (chicory roots) have demonstrated that:

- boar taint is reduced to an acceptable low level
- the taste of prepared pork is improved
- the infection levels with certain intestinal parasites and bacteria are reduced
- the ammonia emission from pig stables may perhaps be reduced

Organic pork deviates from conventional pork with regards to several qualities such as a higher content of poly-unsaturated fatty acids. This is due to the sources of protein specific to organic feeding strategies as well as the mandatory feeding with roughages. Sometimes, organic pork is less tender than conventional pork, and this is due to the lower growth rate in the organic production systems.

The higher content of poly-unsaturated fatty acids in organic pork is beneficial from a human consumer perspective, however, theoretically the meat is thereby more susceptible to oxygen and rancidity. Preliminary results, however, do not indicate that meat of chicory fed pigs tend to go rancid more than conventional pork. In contrast, the studies indicate that the eating quality of the cooked meat from chicory fed pigs has a characteristic more bitter and acid taste, which a tasting panel perceived as positive. The level of bitter and acid taste in the cooked meat increased with the amount of chicory in the feed, but even at high concentrations of chicory, the meat had a fully acceptable quality with a very characteristic taste.

The studies on composition of fatty acids in beef, e.g. conjugated linoleic acid (CLA), demonstrated that both feeding and breed (Jersey versus Holstein-Friesian) had great impact on the CLA contents of the tallow. It is believed that CLA may be health promoting in man.

Future perspectives for organic meat production

The project has contributed to the scientific knowledge on which practical guidelines and decision support for organic meat production has to be based. The application of bioactive crops for improvement of meat quality, including a reduction in boar taint and the elimination of parasites, is a novel and promising new idea. This may lead to reduced use of medicine, reduced risk of residues in the product, and the farmers may avoid long slaughter withdrawal periods.

The combination of production of steers based on grazing and an increase in biodiversity on marginal lands is highly beneficial to the environment and the preservation of landscape. It is expected that the suggested changes in the steers production systems will improve the productivity. The results of the project have also rendered visible the increased expenses associated with organic production, thus justifying a higher price for the final product. In brief, the project has demonstrated that organic livestock production can positively contribute to the natural value of our farmland.

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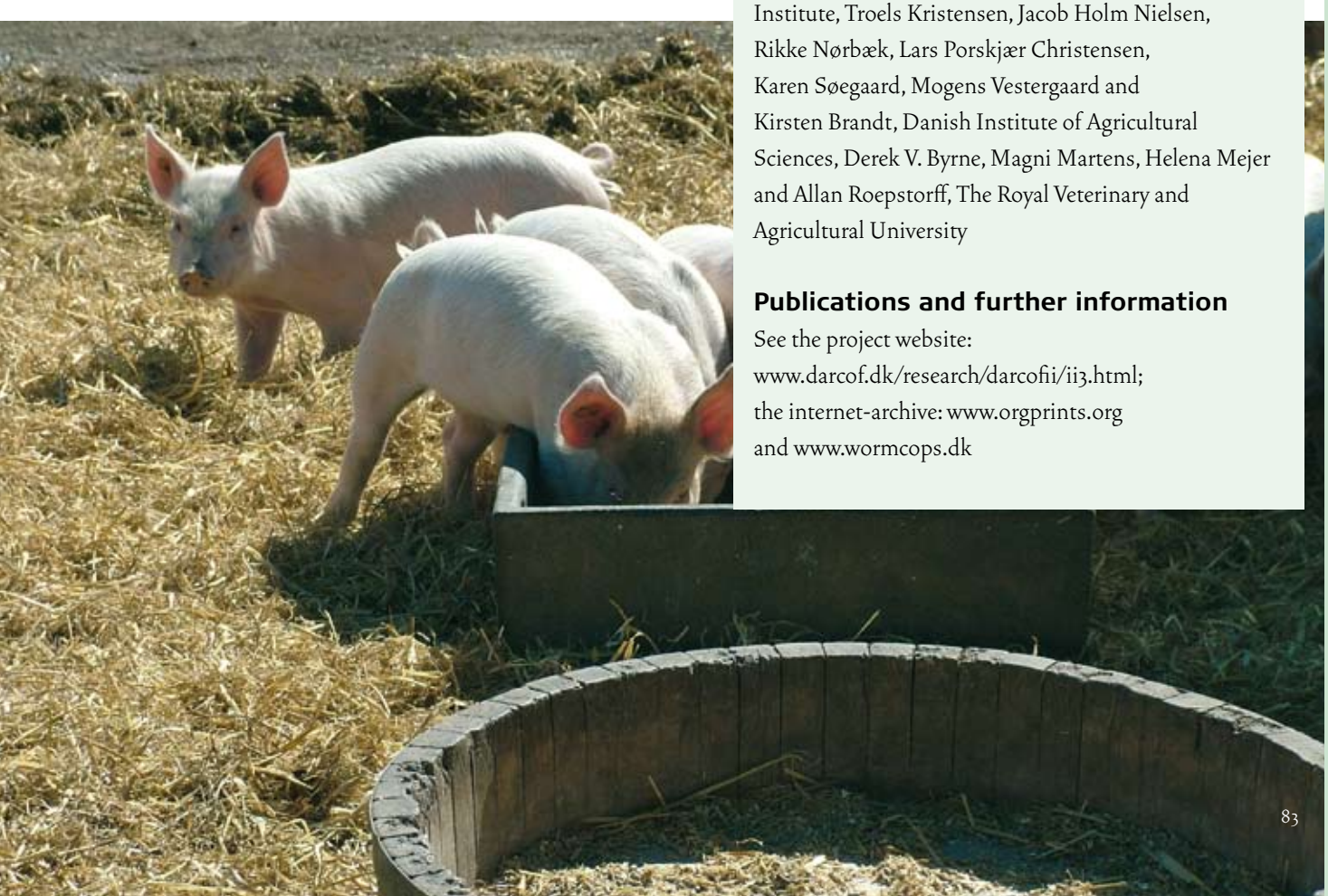
Publications and further information

See the project website:
www.darcof.dk/research/darcofii/ii3.html;
the internet-archive: www.orgprints.org
and www.wormcops.dk



Health and welfare for organic calves

During the past years, we have gradually gained more and more understanding of the concept of animal welfare specifically in organic herds, where the idea of 'naturalness' has great importance. In a dairy herd, it is of course not possible to offer complete natural environment for cows nor calves, but it is relevant to work towards a situation where all animals are given the possibilities to perform natural behaviour, a high degree of freedom of choice, fresh air, daylight and access to outdoor areas. It will, however, challenge the human caretaker more, because he or she has to watch the animals more carefully and be more careful in the observation and judgement of the condition of the animals.

What is 'good animal welfare' in an organic herd?

In an organic herd, animal welfare is very much focusing on the balance between giving the animals as much 'natural living conditions' as possible, and at the same time live up to this as the humans taking care of them in terms of careful observations of the animals and intervention in any case of crisis, preferably before any problems emerge. The calves were in focus in this project because they represent a group of animals, which very often are overlooked in the organic herds.

Assessment of the animal welfare among dairy calves

The calves form a group of animals, which in many ways is vulnerable towards disease and dependent on being offered good healthy surroundings to live in, in terms of space,

light, air, a high level of hygiene and a good and healthy feeding. In the project, we developed a method to asses their welfare with the aim to facilitate the dialogue among farmers, or among farmers and advisors in the concrete herds.

We have developed the animal welfare assessment method in an iterative process involving theoretical considerations ('how to understand the concept of animal welfare in organic herds?'), practical hands-on assessments and discussions both in an international and a Danish expert panel, where practising veterinarians, farmer consultants, farmers and inspectors from the Danish Plant Directory as well as representatives from the organisation 'Animal Protection' participated. The resulting calf welfare assessment is now in use in organic herds in practice and available at the website of Danish Association of Organic Farmers, although there is still room for evaluation and improvements.

Calves grazing under quite natural conditions in terms of light, air, access to shade and various types of grasses, plants and types of landscapes

Practical 'hands-on'-testing of the calf welfare assessment system, followed by discussions about the methods and development of the assessment system

Coccidiosis in organic calves

One of the concrete disease problems among organic calves is coccidiosis. It is an inflammation of the intestines caused by a endo-parasite, Coccidia, some of which are found as winter-infections among group housed calves, and some are involved in summer-infections on grass. Both versions have major impact on the animals' growth and welfare. In this project, we chose to focus on the winter version. We carried through a cross-sectional survey in 25 organic herds, followed by a longitudinal case study in six herds, where a number of identified calves were followed over a period of six months through sampling and descriptions of their surroundings and living conditions. The following tendencies and conclusions were drawn from the study:

- The cross-sectional survey among calves in 25 organic herds revealed a high prevalence of coccidiae, which apparently was not associated with the presence of signs of clinical disease among the calves.

- Clinical examinations, recordings of the environment and sampling in 6 organic calf herds were carried through over one winter and spring. Each herd contained 'it's own individual history' because the patterns were very herd individual. However, there was a strong tendency that there was a relation between the presence of coccidiosis and the level of hygiene in the herds, including the hygiene level in the calving boxes.

- In many herds, both the indoor and outdoor areas for calves were characterised by a poor hygiene. It seemed that coccidiosis was not a primary problem in the herds, but just proportionally following the lack of good management and planning of the movement of animals and the grazing season.

- Feeding, in particular with hay, seemed to have a positive effect against coccidiosis. The calves can very well carry the infection without being clinically ill, but a general good condition and 'robustness' in the herd apparently had great influence on their reactions to the infection in terms of clinical disease.

- Some farmers gave their calves naturally derived Vitamin E. The sampling material was too scarce to base any firm conclusions at, but there was a strong tendency that it influenced the general health situation of the calves in a very positive way.

- Continuous inclusion of new calves to existing flocks seemed critical for the health status of the calves.

The calves' need for possibilities to suckle is natural and important to fulfil

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/ii4.html
and the internet-archive: www.orgprints.org

Antibiotic treatment and antibiotic resistance

Organic dairy herds are characterized by restricted use of antibiotics for therapy, partly because of longer withdrawal times. Reduced use of antibiotics is expected to reduce the risk of development of antibiotic resistance. Restricted use of antibiotics can also have negative effects if sick animals do not get the optimal medical treatment.

Analyses of antibiotic resistance of *E. coli* bacteria from faecal samples of calves have shown, that the prevalence of antibiotic resistance is highly correlated to the age of the animals. Antibiotic resistance is most prevalent in calves about one month old and rapidly decreases with age. Herds with low or reduced antibiotic usage were characterized by putting emphasize on good hygiene, access to outdoor all year, selection of robust animals and usage of sires with high mastitis resistance.

The groups of bacteria causing infections in livestock are expected to be the same in conventional and organic herds. However, we still have only limited knowledge about the prevalence of antibiotic resistance and eventual changes after conversion to organic production.

The aim of the research project was to collect data about the usage of antibiotics for treatment of mastitis in organic dairy herds. In the same herds, the prevalence and dynamics of antibiotic resistance was described. The results were combined with results from other organic and conventional herds. Based on the initial survey, a plan for control of antibiotic usage and resistance was made in the herds.

Antibiotic resistance

The analysis of antibiotic resistance of *E. coli* in faecal samples from calves showed that the prevalence of resistance is highly correlated to the age of the animals (Figure 1). The highest prevalence of resistance was seen in calves about one month old, and the prevalence decreased with age. Based on the collected samples, it was not possible to show any long-term connection between treatment of individual animals and the prevalence of resistance.

In USA, organic animals loose their organic status if treated by antibiotics. New studies show differences between organic and conventional herds in the USA regarding resistance of mastitis bacteria. Data from the herds in the Danish study were used in a study comparing herds in Den-

mark and Wisconsin. The analysis showed lower prevalence of resistance of Staphylococcus aureus in Danish herds, but no significant differences between organic and conventional herds in the two countries.

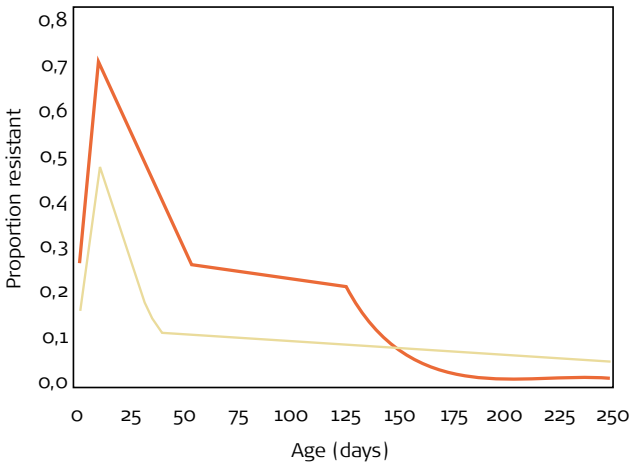

Figure 1. Proportion of E. coli -resistant bacteria (thick line) from faecal samples of calves in relation to age

Use of antibiotics

The use of antibiotics for treatment of udder infections was registered in five herds. A large variation was seen among the herds. Based on interviews with the farmers and veterinarians, the most important factor for choice of antibiotic seemed to be the veterinarian and not herd specific factors.

Table 1. Use of antibiotics for treatment of udder infections in five herds in 2001. Proportion of treated cases in percent

Antibiotic	Mean. (%)	Min.	Max.
Narrow spectrum penicillin	29	11	41
Narrow spectrum penicillin and streptomycin	9	0	29
Broad spectrum penicillins[2]	24	17	26
Cephalosporins	17	1	29
Macrolides (esp. spiramycin)	4	1	9
Sulfonamide/trimetoprim	4	0	13
Tetracyclines	6	0	23

[2] Ampicillin, amoxicillin, cloxacillin

In 2003, twelve herds were selected for further studies in reduced antibiotic usage. Six herds already had a very low usage of antibiotics and six herds were selected because they indicated that they wanted to reduce their use of antibiotics. These twelve herds were visited in 2003 and herd specific plans were developed based on the farmer's aims. The herds were followed in 2004 based on data in the Danish cattle database and changes were described. In both groups, a reduction in the number of mastitis treatments and somatic cell counts were seen. But because of large variation between the herds, the changes cannot be regarded as statistical significant.

Table 2. Development in udder health in six organic dairy herds with very low antibiotic usage, and six organic herds indicating interest in phasing out antibiotics (AB) in the project period 2003-2004 and data from 76 organic herds that did not participate in the project.

Group	No herds	Herd size (cow years) 100 cow years	Mastitis treatments /	Somatic cell count (SCC) * SCC *	% cows with chronic elevated SCC *	% Cows with new acutely elevated SCC *	Culling rate %
Very low AB usage 2003	6	75 (29-142)[1]	3[a](0-5)	324[b] (180-550)	14 (2-40)	3 (1-4)	29
2004	6	77 (30-162)	0[a](0-1)	281[b] (144-479)	22 (2-39)	4 (1-5)	35
Interested in phasing out AB 2003	6	90(56-125)	37b(22-55)	221a (140-260)	14 (3-15)	3 (1-3)	3
2004	6	87 (56-124)	26a(7-58)	214a (180-220)	15 (9-18)	3 (1-4)	39
Other organic herds 2003	76	105	45b	292	30	3	34
2004	76	107	41b	270	29	3	35 [1]

Numbers in parenthesis are max. - min. values
[a,b] Means marked with different letters are statistically significant (P< 0,05)
* Calculated from the monthly production control

The herd owners that had no or a very low usage of antibiotics emphasized a number of reasons for the limited usage. In general, good hygiene in the barn and other measures to reduce transfer of infections were described as the most important elements in keeping the usage of antibiotics low. In several herds, the cows had access to an outdoor area the year around and the importance of having a very open barn with lot of fresh air was emphasized. Selection of robust cows and the use of sires with a high index for mastitis resistance were mentioned as important long term strategies.

Differences in treatment strategies

Some of the herds used nursing cows to feed the calves. For the small calves, it was often cows with elevated cell counts, but in a few herds, larger calves were used to keep cows with acute changes in the milk milked out throughout the day. Cows with high somatic cell counts and reduced production in a single quarter were dried off on that quarter in many herds.

Large differences were seen in the value that the farmers saw of treating cows with udder infections. In some herds, plant medicine and different alternative treatments were used in stead of antibiotics, whereas in other herds, the farmers emphasized that they preferred to use more time on prevention in stead of treating individual animals.

Two different views on treatment affected the strategy for usage of medicine in the herds. In some herds, disease treatment was seen as an annoying and disturbing element in the daily routines. In other herds, antibiotics were seen as an easy solution of a problem. In several herds, a development was seen in which antibiotic treatment changed from being a natural element in the production to a disturbing element that could and should be avoided by optimizing the management routines. In one of the herds, no change in the usage of antibiotics was seen. In this herd, the owner expressed that mastitis was always treated by the veterinarian because it was the less time consuming activity.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/ii5.html
and the internet-archive: www.orgprints.org

Research in poultry production systems

The organic egg production in Denmark has the fundamental problem that the breeding birds, which are available has been genetic adapted to the conventional production in cages. This harms the welfare of the birds and the income of the farmer. There have not yet been identified breeds of poultry that is particularly suitable for organic egg production. In the research, there are pointed at few breeds, which are directly unusable. Further, there has been found co-variation between the health of the hens and the system of rearing. It is therefore important continuously to improve the conditions in which the chickens have been raised. Finally, a population of hens, selected for low tendency to feather pecking, has shown a considerable better feed efficiency.

The breeds also play a role in the organic production of broilers. A difference has been found between two breeds regarding the use of perches and the incidence of breast blister.

The organic production of eggs for human consumption in Denmark has during the period from 1995 up to now increased from few per mill to 15 % of the production. A fundamental problem in the production has been that the breeding birds available are genetically adapted to the conventional production in cages.

The purpose of this project has been to improve the welfare of the organic raised poultry and at the same time give the farmers a better and more stabile income from the hens, and this is the basis for research in production-, health-, behaviour-, and management-related problems. The interaction between these factors and the use of the various breeds of laying hens and broilers used in organic free-range systems has also been included in the research.

The hens are satisfied with just looking at the snow

The project is a continuation of a more fundamental research program carried out during the DARCOF I. In this project, focus has been on laying hens in private herds.

Comparison of poultry breeds

Among the 8 hybrids of laying type that have been compared in couples in herds, little has been found as regards production parameter, although the Danish Hellevad Cross had a little lower production potential. Regarding the conditions of the plumage, there is a large variation among these 8 hybrids towards the end of the laying season. Some of the Lohamnn hybrids show better plumage condition while ISA Brown and Hyline Brown were clearly poor. As to the use of the field on the free range, the Hellevad Cross has the best use while the Hyline White birds were really difficult to get outdoor at all. At a station test at Research Center Foulum, we have seen a somewhat similar pattern. The overall pattern is that no one of the Hybrids is a clear candidate for organic egg production, but a few might be rejected because they are too poor in one of the criteria.

Health condition in the herds

10 herds have been under observation during the project and there is still a considerable mortality due to infectious diseases in some of these herds. Among these, the Black Head disease, which actually is a turkey disease, also affected some herds of laying bird. It has turned out that an unfortunate combination of rearing and infection with endogenous parasites has caused some diseases at the time of start of lay. It is the impression that a part of the variation among herds is due to the preceding period of rearing, and it is suggested that a larger effort is necessary to overcome this problem. A large quantity of dead hens from these 10 herds has been post mortem examined, and the results from these investigations are the background for a PhD study, that will be concluded in 2006. This thesis deals with the interaction between the various infection diseases seen in relation to various management systems in organic herds.

Selection for less tendency to feather pecking

The population of hens that through 6 generations has been selected for low tendency to perform feather pecking has also shown to have a considerably higher feed efficiency also after correction for egg production and body weight compared with the base population. The reason is partly a less loss of heat due to a better plumage cover, but also a less basal activity level. It is taken as a positive sign that the birds, through selection for low tendency to feather pecking, also become less active, but this may not cause other unfortunate changes. In order to check these, we have various investigations running in which we examine if selection for and against tendency to feather pecking has caused changes in egg production capacity and physiological stress response. Preliminary results show that birds selected for larger tendency to feather pecking have a lower production of egg mass while the low feather pecking selected bird

seem to have the same level of egg production as the control population. The deeper understanding of these observations is not yet obtained, but a support from the Danish Research Council has made it possible to study that in more detail. The idea is to identify the genes that are of importance for the tendency to perform feather pecking such that these genes can be taken into account in choosing the right birds in the breeding work for a hen that is more suitable for the organic egg production.

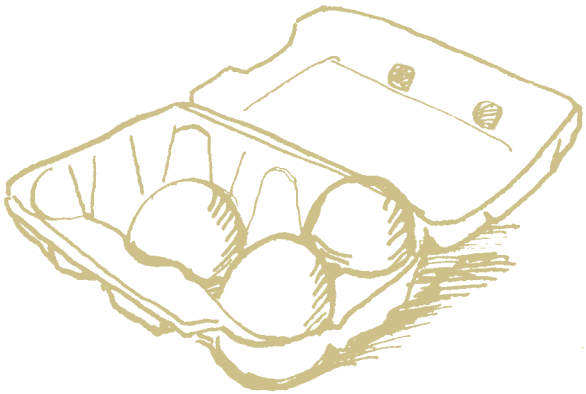
The laying hens keep down the vegetation (5 m² per hen)

Breast blister in broilers

The hybrid used in the Danish production of organic produced broiler and another slow growing breed were used in a comparison test in which focus was on the use of perch and occurrence of breast blister. Breast blister is an injury caused by the pressure against the skin on the keel bone when the bird is resting. In the mild form they appear as a whitish and liquid blister. In more serious cases, they are dark and full of blood at the size of large coins. Breast blister is actually a thickening of a naturally occurring bursa the function of which is assumed to be a buffer between the chicken and the bed they rest on. The incidence of breast blisters at broilers

was investigated at the outdoor system of Research Center Foulum. The two breeds investigated were both found to have a higher incidence of serious breast blisters (7.5%) at full access to perch and partly access to perch than for the group of chickens with no access to perch (2,5%). No difference in incidence of the mild version was found between the two groups.

Chickens of the "I657" breed from ISA were compared to a slow growing breed named Labresse. All chickens had access to perches from hatch to slaughter. The Labress chickens had a weight at slaughter of 200 g less than the I657, and they had a considerable higher incidence of breast blisters even though they used the perch to a less extension. Thus, the risk of developing breast blister is higher at some slow growing breeds than at others and further, it was found that male chickens had more breast blisters than female chickens. The results indicate that even access to perches can be associated with a higher occurrence of serious breast blisters, the breed and the sex has a higher influence on developing breast blisters.



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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/ii6.html
and the internet-archive: www.orgprints.org

Feed and feeding strategies in organic pig production

In organic pig production, there are relatively few sources of feed with a balanced and sufficient level of amino acids, especially feed that may be grown on the pig farm. On this basis a number of investigations were carried out in which lupin was tested as a substitute for the more conventional protein-rich feed-stuffs.

Lupin seems to be a suitable protein source in organic diets. Mixed diets with lupin and chicory root showed good protection against dysentery, and they probably also prevent against infection with whipworm. Further, a high level of lupin in the diet reduced the skatol level and increased the content of polyunsaturated fatty acids in pork.

In organic pig production, it may be difficult to obtain adequate suitable feedstuffs, and this is an increasing problem due to the demand for increased self-supply. In order to fulfil the requirements for essential nutrients in pig diets, it is therefore necessary to find alternative crops and feed ingredients.

The aim of the project is to provide new knowledge on improved diet composition and feeding strategies in organic pig farming. The work includes studies on sows, weaned piglets and finishing pigs. Feedstuffs will be tested in order to meet the pig's requirements with regard to protein, essential amino acids, vitamins and minerals under outdoor conditions. Other studies involve feeding of pigs at weaning, feeding related resistance to gastrointestinal diseases and interaction between feed and meat quality.

Different protein levels in diets for finishing pigs

In a trial with finishing pigs, the effect of two amino acid levels (85 and 100% of standard) was examined when combined with increasing quantities of lupin in the diets. Lupin totalled up to 25% of the diets. The results show that organic finishing pigs can be fed at a lower amino acid level than the standard level set for conventional pigs without causing any serious changes in pig performance. Under conditions where addition of synthetic amino acids is not a possibility, the dietary protein content will be high relative to the requirement for specific essential amino acids. Thus, pigs fed at the 85% level, excrete less surplus protein, compared with the pigs fed the 100% level, as a consequence of a better balance in dietary amino acids at the 85% level. The results also show that lupin is a suitable feedstuff in organic pig farming although the high level of protein (25%) resulted in reduced pig performance. The reduced performance is probably caused by the high level of protein in the feed that is evoked by the deficiency of methionin and lysine in lupin. Therefore, the excretion of N and P rises at the high lupin level.

Digestibility and balance trials with finishing pigs were carried out with 4 diets from the above mentioned trial and on diet of organic lupin. Among the four diets, there was no difference in the digestibility of protein (78%), phosphorus (48%) or zinc (20%). The digestibilities in lupin were 85, 48 and 30% for protein, phosphorus and zinc, respectively. The pigs from the trial were slaughtered at Research Centre Foulum, and samples of the carcasses were taken for quality determination at the Danish Meat Research Institute in Roskilde. The pigs fed at the high level of lupin (25%) had a lower content of skatol in their back fat (0.028 ppm) compared to those not given lupin (0.058 ppm). Furthermore, pigs fed at the 85% amino acid level had the highest percentage of intramuscular fat. Both at protein- and lupin-level there was an effect on the ratio of fatty acids. Relatively less polyunsaturated fatty acids and more saturated fatty acids were seen at the low protein level. The high lupin level resulted in relatively less saturated fatty acids and monounsaturated fatty acids but more polyunsaturated fatty acids. The lupin and protein level did not affect the meat quality significantly.

Lupin

High level of roughage for pregnant sows

Trials with pregnant sows fed at high levels of roughage – by grazing in the summer and feeding of silage in the winter – showed that approx. 60% of the energy requirement can be met when rotational grazing is used, and 40% when pigs are fed with clover grass silage ad libitum in the winter. The results further indicate that in the concentrate, which must be used as supplement to grazing or high quality silage, the content of protein can probably be reduced. In addition, grazing and feeding with silage could cover the vitamin A and E requirements. Analyses of blood and milk further indicate that the supplies of calcium, phosphorous and zinc were sufficient.

Effect of feeding intensity and diet composition on weaning diarrhoea

The effect of feeding intensity, protein level, E-vitamin level and inclusion of lupin on weaning diarrhoea was investigated in piglets weaned at 7 weeks of age. Piglets were inoculated with *E. coli* O149, and only piglets from sows, which were susceptible to *E. coli* were used in the experiment.

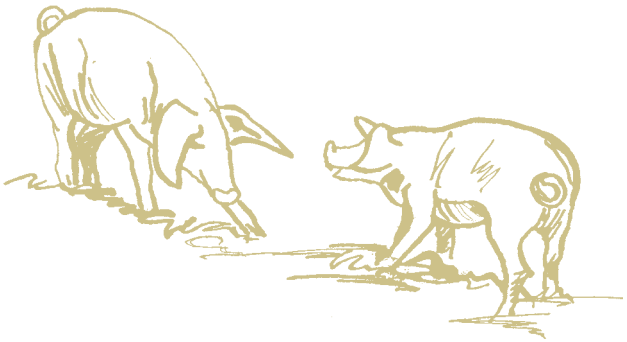
The results show that high feeding intensity reduced weight gain as expected, whereas no effect was seen on the degree of diarrhoea. Low level of protein reduced the degree of diarrhoea and also showed a tendency to lower growth rate. Lupin had no effect on diarrhoea frequency and thus can be considered a suitable protein source for weaned piglets. Also additional E-vitamin had no effect on the occurrence of diarrhoea, but the E-vitamin status of the piglets was improved.

Effect of diet composition on gastrointestinal infection

Earlier studies have indicated that infection with whipworm is affected by the carbohydrate composition in the diet. On that basis, experiments have been conducted with two organic diets: Diet 1 (with rape seed cake and silage) and diet 2 (with lupin and chicory root). Half of the pigs in the experiment were infected with eggs from whipworm (*T. suis*). Results indicate that diet 2 (with lupin and chicory root) may have a preventive effect on infection with whipworm. However, due to large variation in the data, the differences are statistically insignificant. The two diets affected the gastrointestinal environment differently with regard to pH and concentration of short-chain fatty acids. The possible preventive effect of diet 2 on infection with whipworm is obviously caused by changes in the gastrointestinal environment.

Experiments with the two diets above together with a conventional diet, based on pelleted barley, oat and soya, were performed. The aim was to study the effect of the diets when pigs were infected with the bacterium *Brachyspira hyodysenteriae* that causes swine dysentery. Results show that infection with *B. hyodysenteriae* reduced weight gain. Also, a connection was seen between the occurrence of bacteria and the clinical symptoms of dysentery. Diet 2 (with lupin

and chicory root) appeared to provide good protection to dysentery compared with the conventional diet. Infections with *B. hyodysenteriae* and eggs from whipworm in different combinations were also examined. The results show that diet 2 (with lupin and chicory root) protected against dysentery. The pigs given diet 1 (with rapeseed cake and silage) showed, on the other hand, clinical symptoms of dysentery. No clear interactions were detected between infection with whipworm (*T. suis*) and the dysentery bacterium *B. hyodysenteriae* in relation to frequency of dysentery or excretion of eggs from whipworm.



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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/ii7.html
and the internet-archive: www.orgprints.org

Health management in organic pig production

In organic pig production, the aim is to ensure a high level of health and welfare for the pigs, and to secure a high safety level of products. Therefore, research is carried out to contribute to the development of strategies for the prevention and control of problems such as diseases, zoonoses and reduced welfare.

The project has, among other things, shown that housing in an environment infected with roundworms has resulted in high and constant levels of infection right up until slaughtering. Although ploughing has been known to reduce the occurrence of free-living stages of roundworm, they can continue to develop and survive long after the fields have been infected. There are evident connections between the layout of outdoor areas and the occurrence of and problems with rats and mice. So, the potential of a "non-poisonous" control of rats and mice in organic pig production is present.

A better health control in organic pig production can reduce problems such as diseases, welfare problems and zoonoses (diseases transferred from animals to humans). Intestinal worms, for instance, are a significant problem in many organic pig productions because the infections result in reduced feed efficiency and reduced growth among the pigs.

The purpose of the project was to examine and develop management strategies for the prevention and handling of specific diseases, endoparasites, zoonoses and welfare problems through:

- Examining the progress of infections with intestinal worms and how the field infection develops and survives in relation to soil treatment
- Development of a HACCP based monitoring- and management system for control of specific diseases, zoonoses and welfare problems
- Development of strategies for the prevention of rodents with focus on rats

Prevention of intestinal worms among piglets

In the spring of 2000, six identical farrowing units were infected in a natural way with the three most common intestinal worms in Danish pigs; large round worm (*Ascaris lumbricoides*), nodular worm (*Oesophagostomum dentatum*) and whipworm (*Trichocephalus dispar*). Afterwards, the

survival (or field infection) of the infectious free-living eggs (round worm and whipworm) and nodular worms has been estimated by means of parasite free tracer pigs and soil samples every spring and autumn. Three of the units have been ploughed every winter and sowed again the following spring.

The results show, that already in 2001, there was a substantial transmission of large round worms, as six litters of piglets born on the units in July were severely infected throughout the summer and autumn. Possibly, an early moderate infection with large round worms among sucking pigs can result in a higher level of infection than if the pigs were exposed to the infection later in life. Up until the autumn of 2003, an increasing amount of the eggs deposited in 2001, from both roundworms and whipworms, have become infectious. The number of infectious eggs is expected to decrease in time, but when the project had finished in the autumn of 2003, the field infections had still not subsided. Therefore, three years after the units were infected, they were still regarded unfit/unsuitable for pigs. Nodular worms did not survive the first winter and will therefore usually constitute less of a problem than the two other worms.

Results from 2002 and 2003 indicate, that ploughing at the units had the maximum effect on the occurrence of whipworms, whilst generally, there was less difference between ploughed and non-ploughed concerning large round worms. This could be due to the fact that the eggs from large round worms are more likely to survive under ground than in the surface of the soil, as well as the repeated ploughing bring the eggs up towards the surface where the pigs then ingest them when they are rummaging/rooting the soil. Because of the significant differences in survival and infection patterns among the three species of intestinal worms, it is necessary to adjust every control/prevention strategy to the worms present in the relevant herd.

Roundworms from pigs

Typical welfare problems in organic sow herds

A panel of ten Danish and Swedish veterinarians and production consultants with experience in advise in relation to organic pig production has contributed with inputs for identification and quantification of disease and welfare problems in organic pig production. According to the experts, the typical welfare problems among the sows are insufficient access to water and wallowing holes, poor body condition and leg problems. The risk factors for poor

body condition are related to the feeding system and feed quality, while leg problems often are caused by poor leg conformation, infections in the joints and hooves, as well as hard, muddy or rough surface of the outdoor area. The most essential problem concerning the sucking pigs is mortality caused by crushing by the sow, which is related to the layout of the farrowing units, litter material, disturbance of the sow and disease in the sow. Further, weaning diarrhoea is stated a problem in weaned pigs. Important risk factors for weaning diarrhoea are poor hygiene and feed quality, especially concerning protein.

Subsequently, a questionnaire survey in which 60 organic pig producers from Denmark, Sweden, Holland, Germany and England participated, has shown, that leg and hoof diseases were not a general problem for the sows and rarely a reason for culling. However, piglet mortality was a problem in more than half of the herds. The most frequent cause of death concerning the piglets was crushing but also piglets that were born weak and low milk production of the sow had an effect on mortality in many herds. Weaning diarrhoea was especially a problem in the Danish, German and Dutch herds, where the pigs are indoor with access to an outdoor area, and in Denmark diarrhoea is a frequent cause of the death for the weaned pigs. In addition to this, there was a frequent problem with arthritis and intestinal worms, and especially the Dutch herds had considerable problems with respiratory infections. Apart from the various housing systems, differences in hygiene, feeding and age at weaning may contribute to the observed differences in the disease patterns in the various countries.

Occurrence of vermin in outdoor pig production

With the intention of analysing the occurrence and risk factors for rodents, 158 farmers with outdoor pig production have participated in a survey. The result showed that rats and small rodents, foxes and hares, were the most frequently occurring wild mammals in the pig folds. The farmers estimated that rats and foxes were the most significant vermin. The risk factors for occurrence of rats and small rodents were found to be:

- Hay and straw-stacks in the fields
- Hedges close to the folds
- Use of automatic feeding systems
- Open drinking troughs

The factors can practically be included in a strategy for the prevention of problems with vermin. Additionally, non-poisonous rodent control is practised through the use of traps, shooting and by keeping cats or dogs.

The occurrence of rodents has been examined over a period of two years (2001-2003) in two organic pig herds. Altogether, 1247 animals have been captured from which 8 % were rats. In total, there were eight rodent-species and two shrewmouse species. The most frequently occurring rodents are field mice and long tailed field mice.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/ii8.html
and the internet-archive: www.orgprints.org

Resource use, environmental impact and economy in organic pig production systems

There is a need to develop new systems in which the pig production is more integrated into land use in order to fulfil the expectations to the organic pig production from different stakeholders.
Our experiments show that outdoor rearing in most of the growing period (or in the entire growing period) offers good prospects in terms of production and meat quality aspects, but there is a need to adapt the feeding strategy to balance feed conversion and daily growth. However, keeping growing pigs on pasture may be problematic from an environmental point of view as it carries a high risk of nutrient loss. This experiment highlights the extreme importance of lowering stock density and reducing the level of dietary N.
Experiments with nose ringing of sows show, that management choices in terms of feeding, animal density and nutrient distribution are at least as important for the enviroment.

In Denmark, the organic pig production is very scarce today and needs to be developed in order to fulfil the expected potential hereof. In the preliminary work for this research initiative it was anticipated that there was a need to develop new systems in which the pig production is more integrated into land use in order to fulfil the expectations to the organic pig production from different stakeholders and probably also in order to make the production economical feasible.

However, such a development raises several questions, which are being addressed in this project. Firstly, there is a need to propose alternatives to ringing of sows in the effort to maintain sward quality. Secondly there is a need to assess grazing strategies for growing pigs in relation to production and environmental impact, and thirdly there is a need to have an overall assessment of the alternative systems in terms of environmental impact and farm economy.

Strategies for growing pigs kept on grassland

Different rearing strategies for growing pigs in relation to growth rate, behaviour and meat quality were compared (Table 1).

Outdoor reared and ad libitum feed pigs had slightly (but significantly) lower growth rate and an increased feed consumption per kg gain compared with indoor reared pigs. The outdoor pigs, which were fed restrictively, had a lower daily gain according to the period of restricted feeding (treatments 2, 3 and 4), but interestingly, no significant

differences in feed consumption per kg gain appeared. Also carcass traits were significantly affected by the treatments. Pigs reared outdoor in the entire period or until 80 kg's of live weight had a significantly higher lean percentage and a lower back fat than the indoor reared pigs. In particular, the outdoor pigs, which were fed restrictively in the entire period, had better carcass traits.

Since problems with too low lean percentage are significant in Danish organic pig production, the results are very interesting in that respect. In fact, the results show that by keeping the growers outdoor in a significant period of their lives, while fed restrictively, the carcass characteristics can be improved without impairing feed consumption compared to indoor reared pigs, but the production period will be extended by approx 10%. We conclude from an overall point of view that outdoor rearing in most of the growing period (or in the entire growing period) offers good prospects in terms of production and meat quality aspects, but there is a need to adapt the feeding strategy to balance feed conversion and daily growth. In the paddocks used, the content of inorganic N was significantly raised compared to the soil outside the paddocks (Example from one replicate in figure 1). On average, the N content in 0-40 cm in- and

Table 1. Performance traits for pigs in different treatment groups; LS means +/- S.E., and P values for significance of differences between treatments

Treatment	Indoor, ad lib	Indoor from 40-100 kg	Indoor from 80-100 kg	Outdoor, restricted	Outdoor, ad lib
Age at slaughtering, days	156	161	170	177	160
Daily gain, g/day	767	729	673	632	739
Feed conversion, MJ ME /kg gain	37.25	40.20	39.86	35.95[a]	42.3
Lean percentage, total	57.5	57.6	60.4	61.9	59.8
Backfat, mm	17.6	18.4	15.9	14.7	16.5
Lean percentage, central piece	61.9	61.4	65.4	67.3	64.2

outside the paddocks corresponded to 144 and 39 kg N ha-1, respectively. There were no significant differences between the treatments.

A prerequisite for efficient nutrient utilisation is a homogeneous distribution of the manure avoiding hot spots. Regarding this aspect, the regular moving of huts, feeding and water troughs, which took place in this experiment, seemed successful as inorganic N, extractable P and exchangeable K, although with some variation, were distributed throughout the paddocks (Figure 1). Considering problems of maintaining grass cover, high levels of nutrient deposition may only be acceptable if followed by a nutrient demanding catch crop or main crop, which will only be possible if growing pigs are on pasture from February to August. Thus, seasonal production seems the most environmentally acceptable way of keeping growing pigs on pasture. For winter periods, other strategies should be explored.

Fig. 1. *Bubble plot of inorganic soil nitrogen (0-40 cm) in- and outside the four paddocks in replicate 4 of the experiment on growing pigs. Each paddock contained one hut (▲) and one feeding trough (■), which were moved every four weeks (from right to left). Here are shown all positions throughout the experiment*

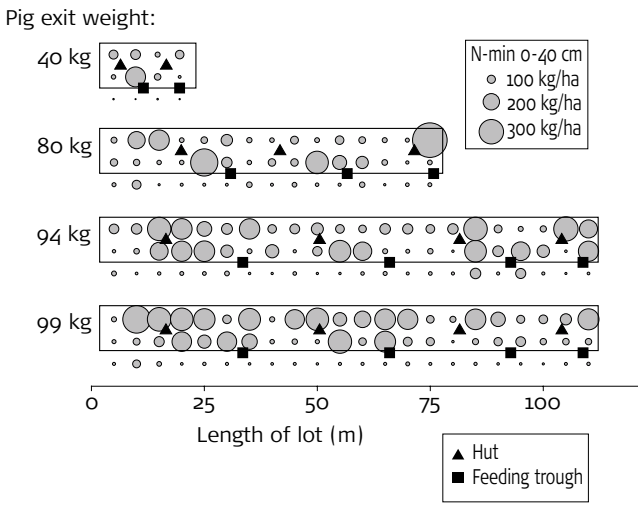
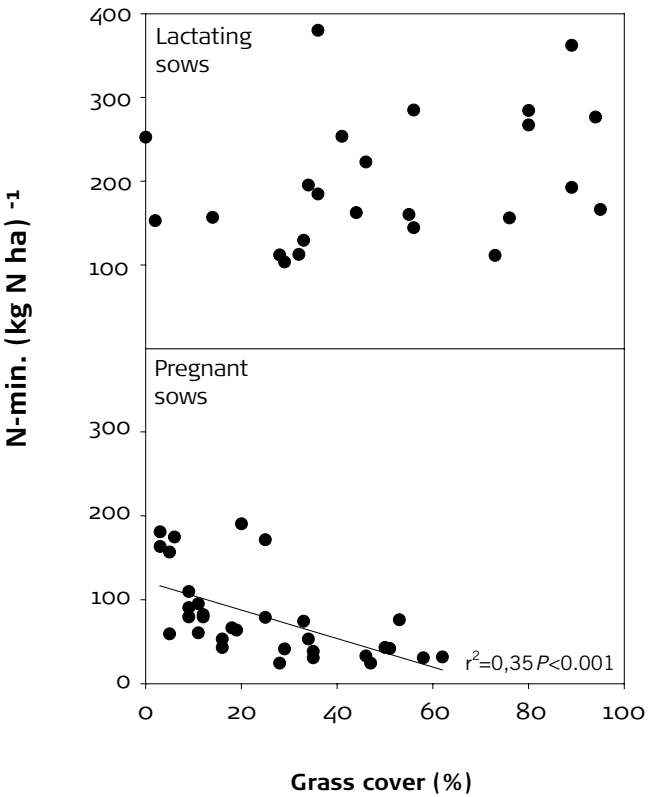


Figure 2. *Relationship between grass cover and soil mineral N content in localized areas of the paddocks*



Nose ringing of sows

The effect of nose ringing on animal behavior and risk for N-leaching was investigated in an experiment including pregnant as well as lactating sows.
Grass cover was better maintained where sows were ringed. As there was always less grass in paddocks with pregnant sows compared to lactating sows, the effect of ringing was more pronounced here. On average, ringing increased grass cover from 14 to 38% and from 64 to 81% in paddocks with pregnant and lactating sows, respectively.

To determine the nitrogen loss potential, soil samples were taken from localised areas in the paddocks for soil inorganic N analysis. In lactating sow paddocks, the level of inorganic N was high but with no significant relation to extent of grass cover (Fig. 2). In pregnant sow paddocks, the soil inorganic N content was significantly reduced by increased grass cover and at 60% grass cover, soil inorganic N content was at a low level.

From the experiment, it was evident that although ringing did have a positive environmental effect, it was not the main factor influencing potential losses. Management choices in terms of feeding, animal density and nutrient distribution are at least as important.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/ii9.html
and the internet-archive: www.orgprints.org

Salmonella and Campylobacter in organic pig production

The animal-friendly extensive systems in organic pig production presumably have a beneficial effect on animals' resistance to infections. However, there is no documentation that organic pigs have a lower prevalence of the most common zoonotic bacteria like *Salmonella* and *Campylobacter* than conventional pigs.

An experiment with organic outdoor piglets showed that *Salmonella* infections is able to spread both between pigs and via a Salmonella-contaminated paddock environment. The level of *Salmonella* exposure seems to influence the establishment of an infection. *Campylobacter* is considered a natural part of the intestinal flora and was detected in all the pigs. Furthermore, besides *C. coli*, which is a typical swine-associated species, it was possible to detect *C. jejuni* in one third of the pigs via implementation of new methods.

Research in zoonotic bacteria in organic pig production

An increased focus on food quality and animal welfare has enhanced the interest in organic, free-range and other alternative animal-friendly production systems, where the animals benefit from a low animal density and good possibilities for expressing normal behaviour. Generally, consumers also expect organic products to be better and healthier than products from conventional production systems. The organic rearing conditions e.g. involve low stocking density and outdoor farrowing with an extended suckling period, which presumably increases the robustness of the piglets e.g. against infections. However, there is no documentation that organic products have a lower content of the most common zoonoctic bacteria that spreads from animals to humans like e.g. *Salmonella*, *Campylobacter* and *Yersinia*. The overall objective of the project was to improve the knowledge on the dynamics behind environmental spread of *Salmonella* and *Campylobacter* within outdoor pig production systems

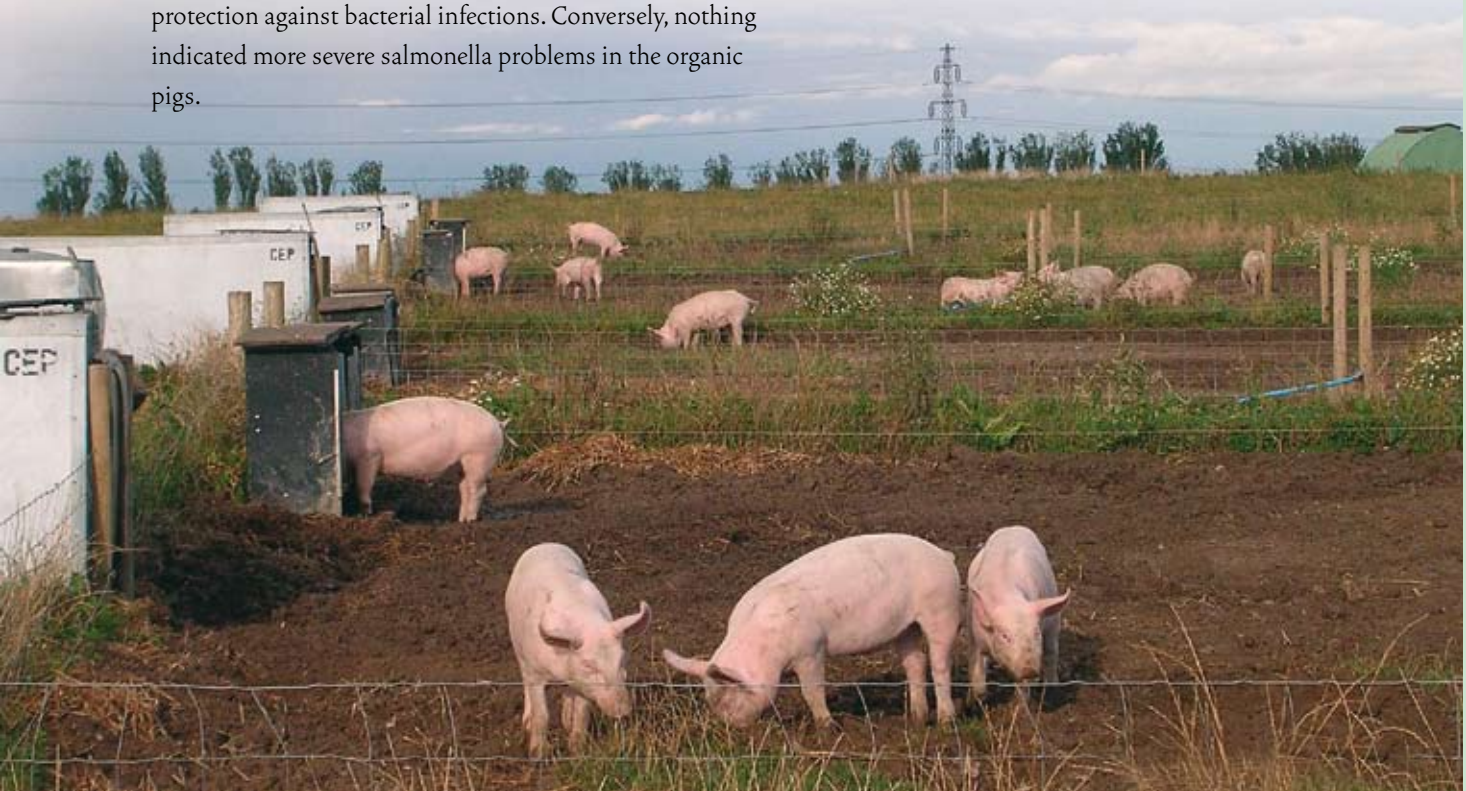
Experiments with Salmonella infections in outdoor pigs

It was interesting to examine how salmonella spread from infected pigs to non-infected pigs under organic rearing conditions and how salmonella contamination built up in the paddock environment including assessment of the potential infection risk associated with the use of such contaminated paddocks for new pigs. The investigations

were performed during the summer 2003 with organically reared pigs right after the time of weaning (7 weeks old). Randomly selected pigs were artificially infected with two different doses of *Salmonella enterica* serovar Typhimurium and then mixed with non-infected tracer pigs to follow the spread of *Salmonella*. Bacteriological testing of faecal samples showed that the inoculated pigs responded quite differently to the infection. Three days after inoculation, some pigs had cleared themselves for *Salmonella*, while other pigs shed *Salmonella* throughout the six-weeks study period. The results showed that *Salmonella* spread to the non-infected tracer pigs because approximately half of these pigs were detected Salmonella positive at least once. The *Salmonella* excretion level was mostly low and the excretion pattern was typically intermittent. The degree of *Salmonella* infection in individual pigs and between groups was quite variable, which is similar to infections in conventional herds. From this study, it cannot be concluded that the organic rearing conditions serve as protection against bacterial infections. Conversely, nothing indicated more severe salmonella problems in the organic pigs.

Examination of soil and water samples from seven specific locations in the paddock showed non-host survival of *Salmonella* and that samples from e.g. wallowing area, water cup and hut were *Salmonella* positive an equal number of times, while *Salmonella* was detected less frequently at the location furthest from the hut. The *Salmonella* contamination level was relatively low in paddocks where pigs were inoculated with a low dose of *Salmonella*, while the contamination level varied considerably in the high dose paddocks. *Salmonella* was isolated from soil samples five weeks after removal of pigs and some huts were *Salmonella* positive after seven weeks when the testing ended. Thus, good hygiene seems important to avoid long-term persistence of *Salmonella*.

To assess the *Salmonella* infection risk associated with the use of contaminated paddocks for new pigs, the infected pigs were removed after six weeks and replaced by non-infected pigs. The *Salmonella* status of these pigs was then followed



for six weeks. The number of pigs that contracted infection from the contaminated environment varied considerably between paddocks where the initial infection pressure was identical. This reflected a big variation in the infection susceptibility of the pigs and that certain conditions may promote a high infection rate. The high infection rate in one of the contaminated paddocks coincided with a pig in the previous period that showed clinical symptoms of salmonellosis with a high excretion level that probably caused a heavy contamination of the paddock environment. This suggests that isolation of animals as soon as a *Salmonella* infection is indicated by clinical symptoms of diarrhoea could be a means of controlling the spread and persistence of Salmonella in outdoor organic pig production environments.

Unexpectedly, several *Salmonella* types besides the test strain, *S. Typhimurium*, were isolated from pigs as well as the paddock environment. A small-scale wildlife study with examination of mice, rats and birds caught in the nearby area was performed in an attempt to identify the source of these *Salmonella* types. However, the animals were all tested Salmonella negative. Nevertheless, the findings of the different *Salmonella* types probably reflects the widespread occurrence of *Salmonella* in nature and that outdoor pigs will be exposed hereto.

Natural Campylobacter infections in outdoor pigs

Campylobacter is considered a natural part of the intestinal flora of pigs. The aim of the *Campylobacter* investigations was to evaluate the occurrence and species distribution of *Campylobacter* over time in outdoor organic pigs. *Campylobacter* jejuni is common in most animals except in pigs where *C. coli* typically dominates, although mixed infections with *C. jejuni* may occur. It is speculated that the higher exposure to *C. jejuni* from the environment may cause a shift towards more *C. jejuni* in outdoor pigs, and that potentially impairs the food safety, as *C. jejuni* is the major cause of human infections. To evaluate this, new molecular methods were developed to estimate the distribution between *C. jejuni* and *C. coli* in pig faecal samples, including the possibility to isolate the species in minority (*C. jejuni*).

The pigs used as Salmonella-negative control pigs in the infection study were used for investigation of natural *Campylobacter* infections in outdoor organic pigs. The bacterio-

logical culturing methods showed that all the pigs were *Campylobacter* positive from the age of 7 to 13 weeks old and there was no clear tendency in the excretion level over time. By implementation of the new molecular methods, it was showed that approximate one third of the outdoor pigs had mixed infections with *C. coli* and *C. jejuni.* This is apparently a higher occurrence of *C. jejuni* than normally seen in conventional pigs. However, it is hard to conclude that outdoor pigs generally have a higher occurrence of *C. jejuni* than indoor pigs, as the detection of *C. jejuni* was inconsistent over time in individual pigs and the prevalence varied considerably between the three groups of pigs suggesting a clumped occurrence of C. jejuni. Comparison of Campylobacter subtypes isolated from pigs, paddock environment, crowbirds and rats showed a few common types, which indicated a possible interaction between sources. However, interaction between different sources was not predominant according to the subtype dissimilarities of most of the obtained isolates from different sources.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/ii10.html a
nd the internet-archive: www.orgprints.org

Consumer interest in organic food products

The Danish and British market for organic food products is fairly similar. In both countries the food market is heavily centralized and industrialized. In order to secure consumer trust, the market is completely dependent on a strong eco-label. Consumers put a great store of faith in organic labels, and expect more from the label than it can actually deliver.

Although consumers associate organic products with a better environment and animal welfare, it is mainly qualities such as health, freshness and flavour that stimulate consumption. Urban areas have a higher spending on organic products, particularly in and around the capital cities, as have households with a higher income, a higher education, and households with middle-aged or older people. The presence of children does not necessarily increase the likelihood of spending on organic products – it actually falls with the number of children in the family. But it is interesting that the presence of smaller children increases the purchase of organic products.

Organic products, now and in the future

The market share of organic products is far higher in Denmark than in Great Britain. But while the Danish development has stagnated since 1999, the British market share is still growing strongly. The main aim of the project was to assess the long-term consumer interest in organic food products. This project focuses on consumer behaviour, i.e. which organic product qualities consumers find most important and how much extra they are willing to pay for these qualities.

Consumer groups

We have divided consumers into four groups, namely heavy users (organic product share more than 10%), medium users (share between 2.5 and 10%), light users (share below 2.5%) and finally non-users. In Denmark the most important organic product is milk, where heavy users have a budget share of 85%, whereas the average for all consumers is 27%. In Great Britain the largest product group is eggs, where heavy users have a budget share of 48% – for consumers in general the average is 6%. Generally, the heavy users are willing to pay more both for organic and conventional foods. Interestingly enough, there are also differences in the general dietary composition between the four groups, i.e. the consumption of organic as well as conventional foods. The higher the organic share of the budget of a household, the lower the use of meat and dairy products and the higher the consumption of fruit and vegetables.

Link with lifestyle

In both countries there is a higher consumption of organic products in urban areas, particularly in and around capitals, in households with a higher income, longer education, and in households consisting of middle-aged or older people. The presence of children does not in itself increase the likelihood of consumption of organic products. Quite the reverse – it actually falls with the number of children in the household. But it is interesting that the presence of smaller children increases the likelihood of organic purchases.

Concentrated distribution and sales channels

The distribution and retail structure in the two countries has much in common. Two to three of the largest supermarket chains thus have the largest market share of organic sales. Less than 15% of organic products are sold through direct channels, such as farm gate, direct deliveries and markets. In certain other countries, this market share is far higher. The direct sales exist alongside the dominating super market sales.

Information and labelling

The Danish eco-label ('Ø-mærke') is known by most people and inspires a great deal of consumer confidence. Surprisingly, there is very little difference between heavy organic users and light or non-users in their knowledge of the regulations associated with the eco label. It is apparently not important to know much about it as long as you can trust it. Danish eco-labelled products enjoy a higher degree of trust than imported eco-labels – and both types enjoy a higher degree of trust than Danish and imported non-organic goods. So although Danish consumers prefer Danish products to imported products, the eco-label can to some extent compensate for this. In Great Britain the situation is not quite as simple, as there are five different eco-labels on the market. It is, however, the dominating and well-functioning Soil Association Logo that is on 70% of all organic products in the country.

Guarantee of quality

Danish consumers generally have a good understanding of the organic principles, but think this is more extensive than it really is. Many consumers believe, for example, that

organic products have to be packaged in eco-friendly, energy-saving materials. Consumers also perceive the eco-label as a general guarantee of a higher degree of food safety, as they think organic foods are associated with a lower risk of bacterial contamination and BSE – i.e. attributes that are not directly encompassed by the organic principles. These wide-ranging interpretations of the eco-label make the market more vulnerable, as it introduces the disappointment factor.

Values and concerns

Heavy and medium organic users differ in certain areas from other consumers. They are generally more concerned with animal welfare and the environment and have an increased awareness of health – they are, for example concerned about pesticide and medicine residues on foods and worry more about the health risks associated with their food consumption. They are less focused on price and are less likely to buy discount. They are more likely to prefer Danish products to imported ones. The most significant consumer barrier is a lack of faith in the adherence to the organic principles, a lack of faith in the health effect and a lack of interest in organic products. These barriers reduce the organic share for all consumer groups.

Qualities of organic produce

We have worked with two types of qualities for organic products. Some qualities are those relating directly to the consumer (private goods) such as improved flavour, wholesome-

ness and freshness. The other qualities relate to public goods such as environmental benefits or improved animal welfare. Although the consumers in the investigation assign twice as much value to eco-health and animal welfare than to flavour, freshness and wholesomeness, it can be concluded that their propensity to buy organic rises with their weighting of the private goods values, while the public goods values of environment and animal welfare have no significant influence. This means that most consumers mean that there are considerable benefits in terms of the environment and animal welfare associated with organic products, but it is mainly the consumers who also think that they are healthier, fresher or better-tasting, who buy the products in the end.

This is an interesting conclusion, because it is mainly the public goods benefits that have been better documented and form the basis for promotions and marketing strategies. About 24% of the respondents claim that they are willing to pay more for organic farming in their taxes, but if they have to pay extra for them in the shops, they must have better consumer qualities. The result is also valid in a number of other European countries.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/iii1.html
and the internet-archive: www.orgprints.org

Analyses of the future development of organic farming

The conversion to organic farming has consequences for farming methods, the economics and the environment. The project has looked at changes at the field, farm, regional and national level due to new technology and changes in legislation for organic farms.

New technologies can decrease the operational costs of producing carrot and sugar beet. As the new techniques mainly are suited for crops in rows, which constitute a minor part of the organic area, the change for the total organic sector will be limited. Tighter rules for organic farming allowing only 100% organic manure, straw and concentrates will increase the costs on some farms. These changes will increase the income on dairy farms, but increase the costs on arable and pig farms. The prognoses indicate a slight increase in domestic consumption and export, but the total organic area is expected to decline due to the oversupply of organic milk.

Analyses of organic farming in the future

The main purpose of the project has been to look at the future economic development of organic farming in a dynamic perspective. The research project is a coordinated effort at the field, farm, sector and national level. At the field and farm level, the focus has been on describing machinery and labour systems as well as the impact of new technology and legislation. The effect of organic farming on the machinery costs pr. hectare is also estimated. These results are used in analyses carried out at the sector and national level. A central part of the project has been to carry out analyses of the future development for the organic sector in Denmark. Key words are the effect of new technology and changes in new legislation.

The project gives a coherent scientific basis, which describe the economic and environmental consequences of the future development within organic farming. On this basis, scenarios for the future development of organic farming, have been analysed. This includes the future supply and demand conditions, new technology, subsidies and environmental regulation.

The results illustrate the effect of different layouts of the agricultural policy for organic farming. The results from the project have also helped to identify problems in the conversion process and requirements, which can lead to further development of the organic production systems.

The conclusions from the project are:

Technical and work issues:

- The time spent on managerial tasks in organic farming is similar to what is spent on conventional farms. The analyses related to the organic pig production show that the operations are carried out efficiently.

- For some crops, the labour usage can be reduced significantly by introducing new technology. The chosen technologies include a weeding robot and band streaming, but also Automatic milking (AMS). These technologies are either on the market or ready as pilot projects, indicating that they will be available within few years.

Farm analyses

- The organic production in Denmark consists mainly of two types of farms. Dairy farms where the owner is full time employed and arable farms where the owner is part time employed and much of the income is earned outside farming. The dairy farms constitute 25 pct. of the organic farms, 50 pct. of the area and 80% of the organic livestock units. The arable farms constitute 60 pct. of the farms, 30 pct. of the area, but only 5 pct. of the organic livestock.

- Analyses show that dairy farms with low livestock intensity would gain economically from converting to organic farming. The opposite is the case for farms with high livestock intensity.

- Tighter rules for organic farming allowing only 100% organic feed, straw and animal manure will reduce the income on arable farms and pig farms and increase earnings on dairy farms. The price of nitrogen will increase and arable farms on Funen and Zealand will find it difficult to get sufficient manure. They will then either change crop rotation or start a livestock production. As the income on small arable farms is already low, this might also lead to a change towards larger and more profitable arable farms. Other farms will swap to conventional farming. The analyses show that there will be a deficit of phosphorus and potassium, why this will have to be supplied from other sources.

- Some new technologies (automatic milking and GPS application of animal manure) have a limited effect on the farm income. Other technologies (weeding robots and band steaming) can reduce the production costs for crops in rows (carrots and sugar beet). However, the total area with these crops is limited.

Analyses at the regional level

- The regional concentration of the total organic production will remain unchanged. The change will be towards fewer dairy farms.

- New technology has only limited effect on the regional distribution of the organic production.

- Tighter organic rules will promote a more even geographical distribution of the organic livestock production.

Analyses at the national level

- The forecast indicate a moderate increase in the consumption of organic foods and a moderate growth in export of organic foods in the coming years.
- The organic area will decrease compared with today in order to ensure coherence between supply and demand of organic products (especially milk).
- The 2003-CAP-reform will on its own contribute to a slight increase in the organic production.

- Tighter organic rules have limited effect on the total organic production.

- New technology has a positive effect on the organic production, but a limited effect on the size of the converted area.

- A steep increase in the demand for organic products requires a shift in the consumers shopping pattern.
- Area subsidy would increase the organic area, but will only have a limited effect on the organic production, as the subsidies will lead to more extensive production.
- Taxation of environmental harmful substances in conventional farming will increase the organic area.
- For all scenarios, the effect on the national income is limited.

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Publications and more information

See the project website: www.darcof.dk/research/darcofii/iii2.html, the internet-archive: www.orgprints.org and www.kvl.foi.dk/English/Publications.aspx

Re-circulation of nutrients and organic matter from urban to rural areas

Urban areas are decoupled from the farmland with respect to re-circulation of nutrients and organic matter. Re-circulation is a basic principle within organic farming, and thus, nutrients entering into urban areas should be returned to the farming systems – but how can this be practiced without compromising other basic principles? What with organic pollutants, heavy metals, disease vectors and GMO's?
The project has examined these questions.
The work has shown that composting strongly accelerates decomposition of GMO-DNA from plants, compared to decomposition in soil. This indicates that composting minimizes risks of propagation of GMO-DNA to the environment. Furthermore, long-term experiments with urban fertilizers will in time provide information about possible undesirable effects of this type of re-circulation.

The project is part of a coherent effort to re-establish the cycle between rural and urban areas and develop urban waste management in order to provide acceptable and useful fertilizers for organic farming systems.

Through the establishment of long-term experiments with urban fertilizers, it will provide possibilities for assessing different types of urban fertilizers with regard to turnover and nutrient availability for crops. In the longer term, it will provide a possibility to assess unforeseen effects on soil quality and production system integrity. With a focus on composting technology, it will provide practically useful results.

The Long-Term Experiment

On The Royal Veterinary Agricultural University (KVL)'s organic farm, a number of fertilizers are added to fixed (900 m2) plots: human urine, municipal sorted waste compost, sewage sludge, NPK and a number of reference organic fertilizers that are in common use in organic farming systems: cattle slurry, deep litter and green manure, and one un-fertilized reference plot. Human urine is delivered from nearby settlements using separation toilets.

Human urine is considered to be the most acceptable urban fertilizer for organic food production. It is very balanced with regard to nutrients and has a negligible content of unwanted components, and results indicate that its effects are close to (and sometimes above) NPK.

KVL's organic research farm "Bakkegården"

On The Royal Veterinary Agricultural University (KVL)'s organic farm, "Bakkegården" a number of fertilizers are added to fixed (900 m²) plots

There is more uncertainty related to the use of municipal sorted waste compost and sewage sludge. Therefore, it was decided to include treatments with these materials at both 'normal' and 'accelerated' rates. After 5-10 years of use, it will thus be possible to assess possible undesirable effects that might occur after 25-50 years of continuous use of the products. Furthermore, it will be possible to detect changes in microbial diversity and function (e.g. Nitrogen fixation) and whether such changes occur before the increase of heavy metals should disturb the diversity and functions. If this is not the case, it would indicate that the products could be used if due consideration to heavy metal content is observed.

Development of composting technology

With support from the EU, we are currently developing a HI-LO (High temperature – Low emission –Low cost) on farm composting technology. This should ensure that composted municipal sorted waste attains a quality that complies with the future EU directive regarding agricultural usage of waste. The goal is to develop a system with minimal odour emission that reaches a temperature of more than 70°C. Such systems can be used in connection with smaller urban agglomerations where nearby farms can take responsibility for the waste treatment and subsequent use, similar to established practice in Austria and Switzerland.

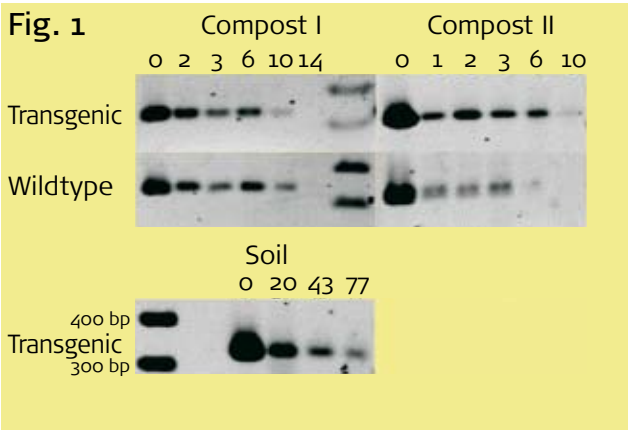

Figure 1. From the figure, it is evident that transgenic DNA is still detectable in soil after 77 days, while it has disappeared after 10-14 days in compost

It is also examined how the sorted municipal waste can be used for the production of biogas prior to composting. Finally, we are working on the possibility of increasing fertilizer value and the ability of the compost to protect high value crops against fungal diseases by addition of chitinous substances before composting.

Decomposition of GMO materials during composting

Our research indicates that composting strongly accelerates decomposition of GMO-DNA from transgenic Arabidopsis, compared with a similar decomposition in soil (Figure 1). After composting in 10-14 days we could no longer find any trace of transgenic DNA in the compost. By addition to soil, we could trace transgenic DNA even after 77 days. If the presence of transgenic DNA in the environment is considered a real problem, the results indicate that composting gives increased security.

This investigation leaves a number of open questions. In spite of assiduous testing, we cannot refute that GMO-material may be transferred to microorganisms during composting. During the composting, there is a strong increase in numbers of Bacillus that is naturally competent in taking up naked DNA. This uptake might give rise to propagation of new genes in the environment. Our research indicates that this did not occur during composting.

It would be relevant to conduct similar investigations under less ideal conditions with lower maximum temperatures and more recalcitrant plant materials. The material we had access to was the very easily decomposable Arabidopsis. Thus there is a need for further investigations in this area, where our work is groundbreaking.

Carbon and nutrient dynamics associated with use of urban fertilizer

In depth studies of decomposition, turnover of urban fertilizers and their impact on soil, microorganisms and fauna are conducted. The project has provided experimental evidence for modelling carbon and nitrogen flows in the soils. The results are used in scenarios for long-term use of composted waste en various farming systems. Finally, selected urban fertilizers are examined for their effects on phosphorus availability, especially their long term effect on soils with a low fertility status.

The project is funded until 2006.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/iii3.html
and the internet-archive: www.orgprints.org

Organic food and health – a multigeneration animal experiment

A method for studying the impact of food on human health is model experiments with animals. Such experiments can be designed so the food is completely controlled and the risk of confounding by extraneous factors is minimised. In the project, rats were fed through several generations with feed produced from plants grown in model systems with three different combinations of organic and conventional methods for fertilisation and plant protection. As in other investigations, there were no substantial differences in the rat's fertility, mineral uptake or feed utilisation. Conversely, the experiment showed that feed from plants grown with organic fertilisation and organic plant protection resulted in the highest antibody levels, least adipose tissue and longest sleep periods. These characteristics have not been measured in previous investigations.

Many consumers expect that organic foods are better for health and more nutritious than foods produced with conventional methods, but scientific studies clearly supporting this perception are missing. There are many reasons why it is difficult to study the influence of diet on human health, among others that a long list of factors other than food influence health, that individuals react differently to food components and last, but not least, that diet affects health throughout life, so our long lifespan makes it particularly difficult to study the effect of food on humans. For comparison of organic and conventional food is it an additional complication that there is a large variation in the production methods used within each of these categories.

Due to this, the project used rats as a model instead of humans. And instead of a complete human diet with both plant and animal products, the feed for the rats was produced from vegetables, fruit and rapeseed oil. It is known that the digestion and metabolism of rats is somewhat different from that of humans, so the results are not directly transferable to humans, in particular not to non-vegetarians.

Investigation of physiological differences

The objective of the project was therefore to investigate, if the difference between conventional and organic food can cause physiological differences in animals, which indicate differences in effects on humans. If differences in diet cause differences in the health of the rats, is it likely humans will experience a difference as well, and that the same aspects of

health will be affected. This knowledge will then allow the design of future investigations to become more targeted and thus with a better chance of reaching a definitive conclusion.

The experiment was carried out with rats that were fed with a mixture of potatoes, carrots, peas, rapeseed oil, kale and apples. The ingredients were processed as for human food and then freeze dried, and were mixed in proportions that ensured sufficient content of energy and protein. These ingredients were grown in 2001 and 2002 in model systems, which represent different methods for plant production:

1. Low input without pesticides: low input of fertiliser; no pesticides (model of organic production)

2. Low input with pesticides: low input of fertiliser; with pesticides (model of production with reduced intensity of fertilisation)

3. High input with pesticides: high input of fertiliser; with pesticides (model of conventional production)

The model systems were chosen to ensure well-controlled growing conditions and to represent extremes in existing cultivation methods. Due to this the feed ingredients do not necessarily correspond to typical organic or conventional products on the market. Those vitamins, minerals and amino acids that can be deficient in a purely plant based diet were added to all three feed mixtures in order to cover the rat's needs for these compounds.

The plant material was investigated for differences in picture forming properties (biocrystallization), in the content of characteristic secondary metabolites and the most important nutrients and minerals, as well as for the biological value of the most important protein sources in the feed.

For the picture forming properties, protein and minerals were only small differences detected in the feed, and differences between the cultivation years were greater than between the cultivation treatments. Some of the secondary metabolites showed the highest and lowest content in the same cultivation treatments in both years, but only few of these systematic differences were significant, and even the significant differences were not very large in % of the average contents.

Minor effect on classic measures of health

The rats were fed with the three feed mixtures; each rat and its offspring received the same diet for the entire life, through three generations. Fertility and growth was recorded for every litter. Female rats from the second generation were selected for more detailed health assessments, which started at the age of 19 weeks, after each had bred one litter. Their health was investigated through physiological response measurements, which comprised nutrient utilisation, organ function and physical activity. After being sacrificed at the age of 44 weeks, samples of blood and tissue were collected for analysis of biomarkers of health, including immunity, antioxidant status and nutrient status.

The rats grew well on all three diets, with only small differences in growth rate and breeding outcome, no significant trends were replicated across the generations. Even though the rats where genetically susceptible to development of diabetes, no symptoms were observed of this disease. The selected rats also only showed insignificant differences regarding the utilisation of nutrients and energy, or uptake and excretion of minerals. These negative results correspond to the conclusions from previous investigations comparing the effect of organic and conventional diets on health of animals or humans, which only showed small or contradictory differences in the effects of these "classic" measures of health.

Differences in antibody, obesity and sleep patterns

However, the new aspects were that we had also included several health measures that had not been used in other investigations.

Even though short-term measurements of energy expenditure did not show any difference related to the feed treatments, there was a trend for rats on feed type 1 (organically grown) had lower weight and lower amount of adipose tissue (Figure 1) than rats from the other treatments. Additionally, rats fed with feed from treatment 1 (organically grown) and 2 (low fertiliser input) had a higher content of immunoglobulin G, which participated in the immune defence against infectious diseases, than rats raised on feed from treatment 3 (conventionally grown) (Figure 1). In contrast there were no differences for the contents of immunoglobulin A and M.

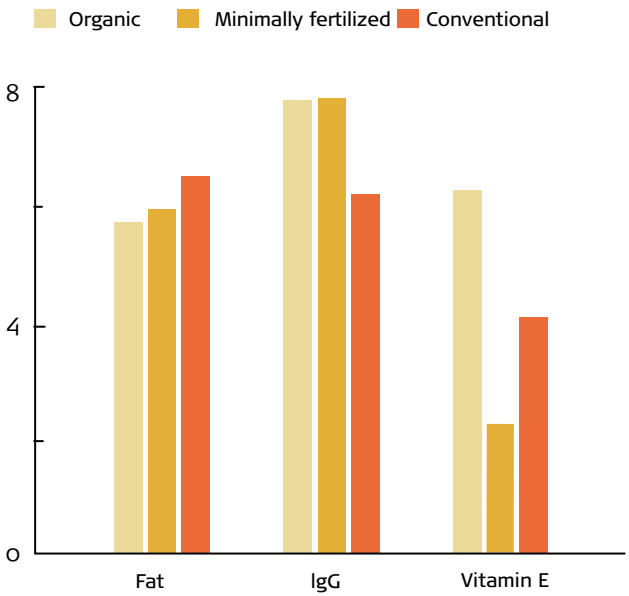

Figure 1. Content of adipose fat in the body (%), and plasma content og immunoglobulin G (IgG, mg/ml) and vitamin E (mg/l) in rats fed organic, minimally fertilized or conventional diets

Concomitantly with the measurement of energy expenditure the physical activity was monitored using infrared sensors. Rats are night active animals, and there was no difference between the diet types for the activity during the night. However, during the day, when rats are expected to rest, the data indicated that rats fed the diet produced with organic methods were quieter than rats fed with the other diet types (Figure 2).

All in all the project showed that exactly those measures of health and well-being, which have not been included in previous studies, showed differences between rats fed with

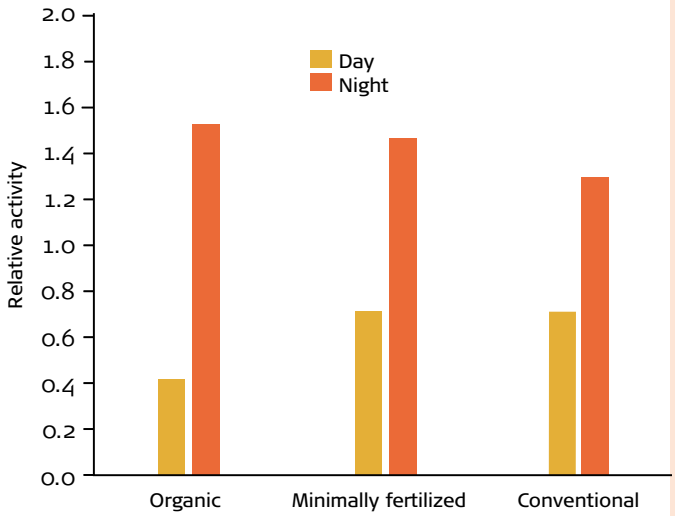

Figure 2. Relative activity of rats at day and night. The rats were fed organic, minimally fertilized or conventional diets

plant materials grown with different methods. In other words, we would not have found any difference if we had only measured the same aspects as in previous investigations, where also no differences were found.

The project has thus shown a clear direction for future research: more emphasis must be placed on the importance of diet for the immune system, lipid metabolism and brain functions, while the production methods for plant foods have less influence on growth, reproduction and nutrient utilisation.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/iii4.html
and the internet-archive: www.orgprints.org

Nature quality in organic farming

The principles of organic farming encourage a diverse crop choice and the development of eco-friendly farming methods. There is, however, very little knowledge about how organic farming affects the surrounding nature in other ways. This project has sought to identify the factors that promote biodiversity in a high-yielding organic cropping system, taking into account the aesthetic and recreational aspects as well. The project has developed new methods of evaluating landscape content, which has identified large differences between organic farms. There is, however, a general tendency towards a larger diversity of plant and insect species in hedgerows and field margins only few years after conversion to organic management. The biodiversity in soil depends on soil type, soil management and manure applications. Other impacting factors are early crops and grazing history. A clover catch crop will lead to a larger content of fauna in the soil, irrespective of soil type.

Organic farming is an alternative to the intensification and specialisation that has taken place in farming in recent years. This project presents the actual status and the future prospects for the promotion of biodiversity in high-yielding organic farming systems. As the farmer and the public have different ambitions and perceptions of the quality of nature, the biological, production and aesthetic aspects are also included.

The project has developed methods of characterising the substance of nature and discusses opportunities and areas of transferring this knowledge between different stakeholders. This work includes analyses of the farmer's motivation for converting to organic farming, the geographical distribution of farms and farm characteristics.

A number of models and principles for the preservation of biodiversity on uncultivated organic farmland have also been developed. The prerequisites for a positive relationship between a high production level and a diverse and varied ecosystem have also been investigated. We have finally analysed the farmer's perception of landscape values, and how this is reflected in the practices on the farm.

Farm distribution and management practices

On the basis of a comprehensive questionnaire, 10% of all organic farmers were interviewed in 2001 on their degree of specialisation, on their farm management and nature protection practices and about farm finances. The distribution of organic farms in Denmark appears to show a certain regional concentration with relatively large areas completely without organic farms. Thus, more than a third of all the parishes in Denmark are completely without organic farms. Historical analyses show that the distribution pattern from 1994 to 1997 is repeated in the 2001 pattern, so the concentration that took place earlier appears to continue. The degree of specialisation apparently follows the usual pattern with a higher concentration of livestock farms in Jutland and a higher concentration of arable farms on the islands.

Continuity and the absence of fertilizer are some of the main prerequisites for a high biodiversity on permanent grasslands. Preliminary analyses of organic farms show that most of the permanent grasslands are very old with a history of more than 40 years of grazing. Only a few per cent of the permanent grasslands receive fertilizer applications and they are mainly those that have more recently been put down to permanent grassland.

Belowground biodiversity

The content of organic matter and diversity of soil-living animals in arable soil improves the natural fertility and structural properties of the soil. The different animal groups, including springtails and soil mites show the link between soil type, soil management intensity and fertilizer application, and the cropping and grazing history. The 430 analysed samples also showed a larger abundance of soil biota under a clover catch crop, irrespective of soil type. Not surprisingly, crop type and grazing intensity were also strongly dependent on soil type. An indicator system for the initial evaluation of soil biodiversity on the background of soil type, crop choice and different treatments will be developed. This will contribute to the setup of a parameter to better describe the biodiversity of soil biota at farm level.

In the crop rotation experiment at Foulum and Flakkebjerg research stations, the air-borne and soil-living arthropods were collected in winter wheat, including insects and spiders. The soil fauna was analysed and the experiments showed surprisingly few effects of fertilizer application.

A 10x10 km area northeast of Herning has been digitalised with a view to using it for scenario analyses. The scenarios are meant to assess the impact of different forms of organic farming on parts or all of the landscape. The effect will be determined by the abundance of ground beetles, spiders and skylarks that are thought to be vulnerable to the changes investigated.

Aboveground biodiversity

The botanical biodiversity of 24 widely differing organic farms were investigated. In 885 randomly distributed sample areas, there were 561 different plant species. The majority of the areas were dominated by the species most commonly occurring on nutrient-rich and disturbed arable land. Only a smaller number represented protected areas such as those in the EU habitat classification.

The investigations show that the diversity of different mosses increased with the extent of the area covered by moss, and that grazing/cutting regimes promote moss growth while fertilization impedes it. Ticks, leafhoppers, spiders and vegetation samples have been collected from 100 ungrazed, well-lit areas in meadows, fens, bogs, set-aside land, commons and wasteland. They represent different degrees of botanical nature quality. Three new Danish species of leafhopper and one of spider were, for example, discovered in these samples. A preliminary analysis suggests that good botanical quality also gives a good quality habitat for arthropods.

Studies on the conversion of a number of livestock farms to organic farms have shown, rather surprisingly, that there are considerably more species of plants and flies in hedgerows and field margins on organic farms already 3-4 years after conversion. The differences become even more noticeable after seven years. The most common plant species tend to dominate, but there also appears to be room for the somewhat hardier species on organic farms.

The farmer as a landscape manager

The farmer is the primary decision-maker on agricultural issues. It is therefore his understanding and prioritising of environmental matters that determines the management of nature quality on individual farms. The project shows that the organic farmer's view on nature and appreciation of what is valuable in nature differs considerably from the views on which scientific investigations on nature quality are based. For the interviewed farmers it is much more the environmental aspects than landscape aspects that are seen as organic farming's positive contribution to social development.

With knowledge of the importance of the emotional and aesthetic commitment to the environment, the potentials of using aesthetic observations of the environment to form a communication bridge between farmers and experts have been tested. Preliminary results suggest that it is possible to develop bio-indicators of nature quality that can be used by organic farmers to monitor the development in nature quality on the farm.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/iii5.html and
the internet-archive: www.orgprints.org

Future supply and marketing strategies in the Danish organic food sector

Organic farming, emerged as counter action to the problems caused by the conventional farming practices. This would be the discharge of pesticides or nitrate to the ground- or drinking water, medicine residuals in food, new production diseases due to the pressure on animal health and the high concentration of animals in large industrial husbandries.
Eighty percent of the organic commodities are sold through retailers. If the organic producers are still to have an influence on the sales of their production, it is necessary that they enter into partnerships with various supermarket chains. This task will demand a quite different way of organizing the organic producers, which in regards to sales, they would have to think transversely of commodity groups and directed more towards the total shopping cart.

Organic farming is often mentioned as a pioneer for a new environmental consciousness, where questions concerning food safety, cultivation of the land and social justice are, among others, connected to a reorientation in the food and farm policy. The procurement of organic food – from farm to plate – seems to go against many of the present trends in production, processing, distribution and marketing of food in general.

However, the explosive growth since the beginning of the1980's is both the cause but also the reason for the creation of many new actors who try to make use of the lucrative niche markets that hides behind the organic label. As a consequence of this, the organic sector experiences rapid changes in its production and marketing conditions as well as a restructuring of the economic conditions that the sector is subjected to.

The purpose of this research project has been to analyse the future development of the Danish organic supply chain with respectively organic pork and organic vegetables as case studies. The main emphasis is laid on identifying the economic forces and changes that operates within the two chains.

On the basis of the research, it has been the intension to identify and explain the restructuring that is taking place within the organic sector and hereby provide with useful marketing strategies for a continued growth in long term perspective.

Possibilities of growth in the organic food sector

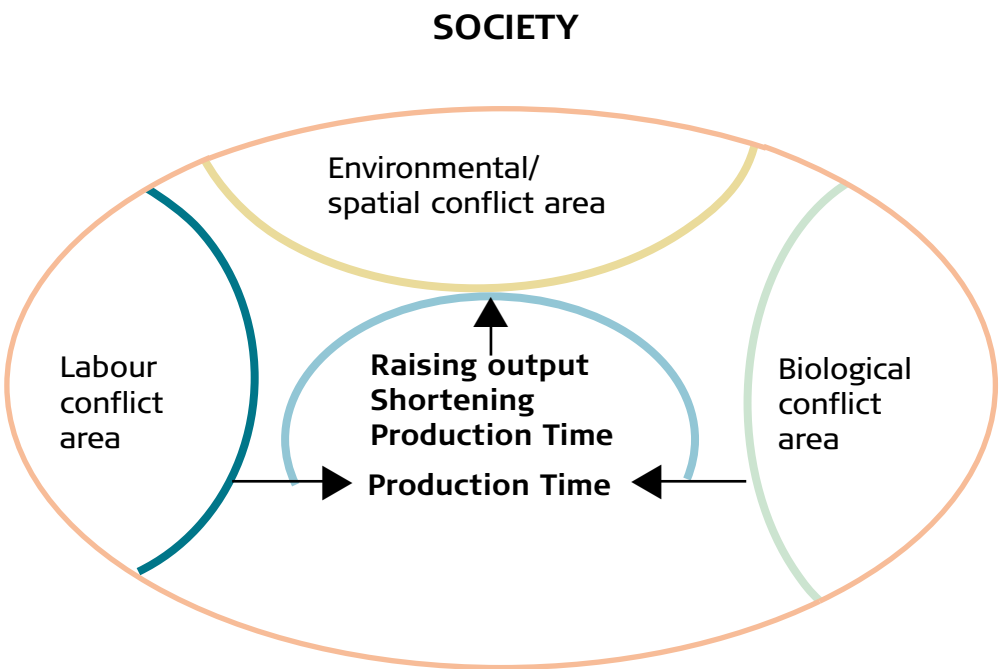
In a competitive market economy, there is an underlying demand of growth in the capital invested. In general there are three ways, in which firms can fulfil this requirement:

- Expand production and make use of economies of scale and scope
- Increase efficiency with the resources in use (labour, animals fodder)
- Increase the production flow by shortening the production time from which an animal is born till it is sold

These mechanisms in the economy, pressuring for growth in the invested capital brings in turn various societal conflicts over time and spatial.

This is illustrated in figure 1, where the arrows illustrate the increasing societal conflicts by pressuring production in time and in scale. The conflict areas around 'labour', 'biology' (animals and plants), and 'environment' (landscape) will increase. The production rules of organic farming try to solve and minimize these areas of conflict by setting up restrictions towards the economic pressure for constantly trying to increase volume and the flow of production.

Figure 1: The connection between the demand for growth in the economy and the societal consequences in relation to agriculture



The organic sector in the future

Even though organic farming with its values successfully has prevailed in creating a market, it still acts within a market economy with its conditions of growth in the capital investments. For that reason, the organic products will be met with the same demands of higher efficiency in the production with lower prices as a result. Especially, when the market for organic products is stagnating the price squeeze will be evident. This pressure for higher efficiency is more and more brought about by the supermarkets, through their conditions concerning deliverables, distribution and competitiveness which will imply declining prices for the producers.

While a diversity of economic and ideological actors still have progress within the organic sector, big agro-co-operations - or successful new comers copying the conventional producers' business methods, are entering the most dynamic and profitable segments of the organic market.

If the organic producers are still to have a high degree of influence on the market prices in relation to the retailers, it is necessary that they enter into alliances and take over the role as a consultant towards the supermarkets regarding product development, design, advertisement and new store concepts.

Supermarkets are confronted with a need for huge store changes to differentiate themselves towards the discount chains. They will therefore have a special quest for commo-

dities based on value with a strong profile, which can create safe and trustworthy shop environments. In return, this will demand a quite different organization of the organic producers, and they will have to think transversely of commodities and more towards the total shopping chart.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/iii7.html
and the internet-archive: www.orgprints.org

Distribution channels for organic foods and consumer trust

Does consumer trust in organic products and producers vary, depending on the sales channel through which products are sold? In order to answer this question, differences between three groups of consumers were investigated. Those who buy their products in a supermarket were compared with those who are members of a box scheme and those who buy directly from a farmer or grower at a market stall in town.

All three groups have some common characteristics, including a thoroughly negative image of conventional farming, a desire to buy healthy, fresh products that taste good, and the experience of being under time pressure when it comes to shopping. But there are also clear differences between these groups of customers. Farmers who use direct sales channels make a very important contribution to maintaining trust in organic products among 'heavy users' of organic products. There is therefore a need to support attempts to establish or expand direct sales channels and other alternatives to supermarkets.

Two phases of investigation

A qualitative sociological study was undertaken in two phases. The first phase investigated the kinds of direct sales channels that have been established in Denmark, positive and negative experiences related to the use of these channels among organic farmers, and which sales channels are worth concentrating on as seen from the farmers' point of view. The second phase, which constituted the core of the investigation, comprised a comparative study of customers who buy their organic products in supermarkets and those who buy them directly from farmers.

Direct sales as seen by farmers

Two sales channels were selected for further investigation on the basis of farmers' experiences. It was clear that the satisfaction with direct sales was greatest among those who had developed a box scheme with weekly or fortnightly deliveries and among those who had established a market stall in a nearby town or city and sold their products there one or two days a week.

Quite a number of farmers had experimented with different kinds of direct sales channels. They expressed uncertainty about how such channels can be developed, and about how one goes about establishing contact with customers. These results indicate a widespread need for professional support to organic farmers with regard to the establishment of cooperative projects designed to promote direct marketing channels.

Aim and method of the consumer study

Data were collected from 12 focus groups during the main phase of the investigation. Four focus groups were recruited among customers at supermarkets, the same number among members of box schemes and among those who regularly bought organic products from a farmer-run market stall. Supermarket shoppers were further divided into two sub-groups: those who bought organic products occasionally and those who bought them frequently.

Participants (108 adults) were recruited by telephone interview. They each took part in a planned and structured focus group discussion of 2½-3 hours duration. Participants were requested to sort and rank products, to tell about particularly good and bad experiences while shopping for food, and to make drawings of both conventional and organic farms, which each of them then described and explained. The analysis of these data compared these groups of customers with respect to differences regarding their concepts and assessments of organic products, producers and methods of food production. This analysis also took into account differences between the social characteristics of these groups of customers (age, gender, education, employment, household composition, etc.), as well as the frequency with which they bought organic products.

Main results of the consumer study

- Contrary to what is often claimed, consumers are far from indifferent to the people behind the products they buy. Both 'heavy' and 'occasional' consumers have vivid images of conventional and organic producers.

- Customers at all three shopping venues share a dominant image of conventional farming as being a form of industrial production, which is focussed on efficiency, large scale production, technological solutions, standardised products and profits. Organic farming in contrast is seen as a form of production in which other important concerns are also given a place.

- There are differences between these groups of customers as regards their image of organic farming and farmers. Occasional buyers tend to have a somewhat nostalgic image of traditional family farms, although half of them do refer to one or more of the principles of organic farming. 'Heavy' users on the other hand, disregarding where they do their shopping, refer to organic principles much more often. Many of them are particularly concerned about one particular issue, such as biodiversity, the quality of our ground water or animal welfare. Customers of market stalls are especially inclined to think of organic farmers as people who care about and care for soil, plants, animals and other people, including their customers.

- What means most to consumers when shopping for food is the extent to which they experience sales people as being indifferent to or proud of their products, and the extent to which they are indifferent to their customers or concerned about their needs and wishes.

- Customers at all three venues want food products that are fresh, healthy and taste good. They reject products as well as shopping venues that do not meet these criteria.

- Occasional buyers of organic products often compare goods in the supermarket. They tend to think of organic products as being a little better than conventional ones on the grounds that they do not contain pesticide residues, have fewer additives or a nicer taste. Heavy buyers on the other hand are more likely to object to conventional production methods in principle and to have decided in advance that all conventional products will be ruled out as far as possible.

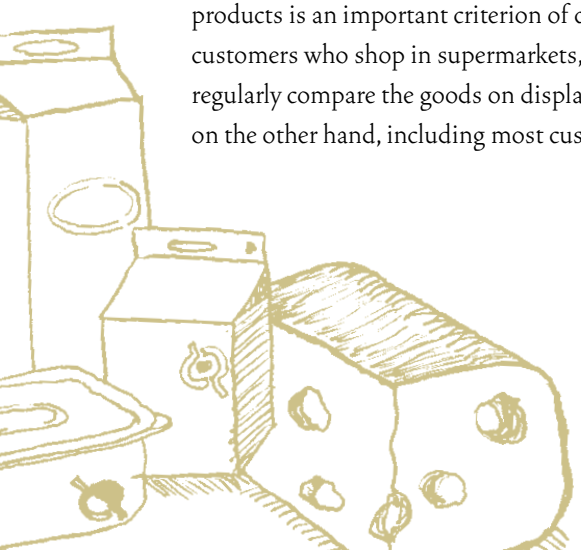
- While occasional buyers say they are looking for good or quality products when they go shopping, heavy buyers say they want decent products or foods that don't weigh on the conscience.

- Disregarding shopping venue, heavy buyers of organic foods place many high demands on the foods they buy. Apart from ruling out conventional production methods, eating quality, ingredients, method and extent of processing, packaging and country of origin (preferably Danish) are important criteria for them. Many of them want local, seasonal produce, as well as credible information about the treatment of products and of employees in the firms they support. They like to support small firms and to avoid large firms when possible.

- Time is an important consideration when shopping, especially among younger consumers. Box schemes can compete with supermarkets on this point. Subscribers to these schemes particularly appreciate the advantages of being to place their orders via Internet and to have their goods delivered to their homes.

- The price difference between conventional and organic products is an important criterion of choice among customers who shop in supermarkets, and therefore regularly compare the goods on display. Heavy buyers on the other hand, including most customers of direct sales channels, make their food consumption affordable by cutting down on the purchase of luxury food items or other products. Some also supplement their consumption with home grown produce.

- Virtually all direct customers express a very high level of appreciation of their selected sales channel, disregarding whether it is a box scheme or an urban market stall. However, those who buy directly from a farmer or grower at a stall distinguish themselves by their expressions of intense loyalty to the particular farmer/grower and his products, both of which are trusted implicitly.



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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/iii8.html
and the internet-archive: www.orgprints.org

The processing of organic foods

Theory and practice

Organic farming is based on a holistic approach and encourages sustainable development. This involves the principles of nutrient recycling and the sympathetic management of nature and the environment. The principles also involves the concept of organic foods being produced and sold locally – the nearness principle – as this enhances the farm-level recycling of nutrients, the exploitation of local sources of knowledge, and the contribution to local culture, etc.

There has for many years been a rise in demand for organic produce on the European market and increasingly so for processed foods – convenience foods in particular. This rise in demand has also resulted in a boost to the international trade with organic products. This has strengthened the focus on the processes and agents that increase the shelf life of a product.

Standards for processed organic foods

Current standards for processed organic foods contain regulations on the use of additives including a ban on those additives for which there is deemed not to be a technological need. The latest EU regulations for animal products indicate, however, a need to more precisely formulate the principles or the objectives for what an organically processed product is or should be. The aim of this project has been to focus on the principles of processing organic products and to contribute to their continued development.

The precautionary principle

A concept often used in the attempt to formulate principles for how organic products should be processed is the precautionary principle. The precautionary principle is thus already

used in several standards for organic food processing. There are currently no precise suggestions for how 'precautionary' should be interpreted.

The concept of a precautionary food production is often approached from a techno-scientific angle. Thus the aspects of precautionary that have particularly been accentuated are those that can be measured or tasted. This may, for example, be the nutrient content, nutrition, hygiene and flavour. From the techno-scientific angle, the concepts of "clean technology" and "life cycle assessments" are used to quantify environmental aspects. These methods are based on a scientific understanding and they focus on the aspect of the precautionary principle that deals with measurable environmental impacts. The precautionary principle can, however, also be applied to a number of other approaches. In social ecology, the precautionary principle is applied to the producer-consumer relationship, the town-country relationship, the 'good life' working environment, and the democracy versus technocracy approach.

The extended precautionary principle

This project has identified three dimensions that can be used to investigate how knowledge from other areas can be used in food production. These are:

- Product (precaution from a product quality perspective)
- People (producer-consumer relationship, work environment, democratic influence)
- Environment (cleaner technology and life cycle approach to quantify environmental aspects)

If specific food manufacturers are analysed in terms of these extended precautionary principles, disparities often become noticeable between the individual elements of the concept. A technical product improvement can, for example, sometimes lead to deterioration in its eco-friendliness and vice versa. And correspondingly, the work environment in a company may be adversely affected by changes to environment and product parameters.

Environmental objectives

The absence of environmental objectives in the regulations on the processing, handling and distribution of organic products is something several companies are aware of. The use of organic raw materials is only one of several initiatives that can be employed by food manufacturers in the improvement of their environmental performance. But other aspects such as the work environment, recycling, energy consumption, transport, water consumption, waste disposal, etc., are also important. If consumer confidence in organic foods is to be maintained, it is very important to demonstrate that the principles apply throughout the chain from farm to fork.

So far, no organic association has stipulated the incorporation of environmental management systems in its standards. The fact that many conventional processing companies

already have implemented such systems in their production naturally puts the eco-oriented companies in a dilemma in terms of promoting themselves as a viable alternative and sustainable choice.

Experts

As the food processing operations become more and more sophisticated, it also becomes more difficult for ordinary consumers to assess the ethical and health effects. An example of this is the EU work on setting standards for the processing of organic meat. For nitrite, for example, it has not been possible for the EU countries to agree whether to ban or allow the compound. The nitrite example illustrates how the organic actors – to a far higher extent than 10 years ago – have to navigate through a sea of opposing interests of markets and ideals, and that the number of actors on the market has increased considerably.

Social and ethical aspects of the production

One of the best-known brands that takes social aspects into consideration is the Max Havelaar brand. This is a label of fair trade and means that the consumers can be guaranteed that these products fulfil some minimum standards for labour wages, working conditions, democratic development and environment. Small-scale farmers and plantation workers are, for example, paid a fair price for their goods and the money goes directly into their own pockets without any middlemen. The Max Havelaar brand has inspired the English organic Soil Association to develop and national or local "fair trade" certification programme, also called "Ethical Trade". This label guarantees a fair wage for the farmers and actors throughout the supply chain and a reasonable wage and working conditions for employees. Certification also involves the company in the local community. In later years the concept of Corporate Social Responsibility has become increasingly important for, in particular, internationally-oriented food manufacturers. The concept implies that companies accept a social responsibility for aspects not directly relating to the activities of the company.

Future regulation of food processing

On the background of interviews with central actors in the organic food organisation, we have identified three main arguments in relation to the regulation of the organic food processing area:

1. The principles as formulated in the current EU regulations are continued, but with the successive adjustments to, e.g., the list of additives and the inclusion of further technical conditions relation to production, such as a ban on certain processing technologies, solvents or packaging materials. This argument represents status quo and is mainly supported by the regulating authorities, but also by several ecological organisations.

2. A more radical widening of the processing regulations is needed to maintain consumer trust in organic foods. Several areas have been proposed, but the three main areas are: the environmental performance of the company (energy and water consumption, discharge and recycling of waste, etc.); the inclusion of social aspects (working conditions, education, community involvement, etc.) and, finally aspects concerning "fair trade". This argument is particularly supported by NGOs (environmental organisations, trade unions, organisations involved in developing countries, etc.).

3. There should be no restrictions in the use of specific additives or production methods, so that there are no special 'organic' restrictions for the processing of food above those already applicable to the food sector. The regulations should only contain provisions for the segregation of conventional and organic products and for labelling. This argument is particularly supported by the more traditional food manufacturers, that have a limited organic product range. They argue that many consumers request organic forms of products that currently are only available in conventional forms.

Ethical traceability

Even in the early days of the organic principles, transparency or traceability was major issues. They are even more important these days, where the distance between the organic producer and the consumer is larger than ever. There is therefore a need for open and transparent retail systems that, for example, communicate factual information about the producers to the consumers. A current EU Sixth Framework project deals with the concept "Ethical Traceability". For an organic food producer, this concept contains a number of possibilities for reducing the distance between farmer and consumer.

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Publications and further information:
See the project website:
www.darcof.dk/research/darcofii/iii9.html
and the internet-archive: www.orgprints.org

Communication based on experimental units for organic farming

A number of field experimental units were established in 1996 under DARCOF for use in organic farming research in Denmark.

These organic experimental units have been valuable assets for organic farming research in Denmark. They have ensured that research activities were conducted on fields with good organic farm management and with a documented history of the sites. Good experimental units should not only be managed organically, but also reflect the variation, farming practices, soils and climate.

The experimental units cover all major organic farming practices and soil types in Denmark.

These units primarily consist of field experimental sites at Flakkebjerg, Foulum, Jyndevad, Årslev, Askov and KVL-Taastrup, and the long-term crop rotation experiments at Jyndevad, Foulum, Flakkebjerg and Holeby. The organic farming research station, Rugballegård, is also part of the set of facilities.

Some of the experimental units have been designed as separate experiments, where the long-term effects of crop rotations, cover crops and animal manure are investigated. These experiments also function as experimental units, where specific experimental and project activities focusing on interactions with soil fertility, cropping practice and cropping history are performed. Examples of this are the possibilities of exploiting residual nitrogen effects, the risk of detrimental soil compaction, the interaction of genetics and environment in relation to crop and cultivar choice, problems with establishment of cover crops, and occurrence of weeds and diseases.

The aims of the experimental units for research in organic farming systems are three-fold:

1. To describe long-term effects of organic farming practices and crop rotations
2. To function as workshop facilities for other, more specific research projects

3. To assist in communication and dissemination of the results of research in organic farming

Experiences from the experimental units

The research station for organic farming, Rugballegård

The research station for organic farming at Rugballegård comprises activities on both crops and livestock production and therefore offers possibilities for studying interactions between plant- and animal production. Three different systems are represented: cattle, pigs and mixed cattle and pigs. The experiences show that the mixed system offers possibilities for increasing crop productivity despite a slightly lower amount of animal manure, which indicates a higher nutrient use efficiency in the mixed system.

Workshop areas at Jyndevad, Foulum, Årslev, Flakkebjerg and KVL-Tåstrup

These workshop areas have been designed with different crop rotations (for cattle, arable crops, vegetables or fruits and berries). The experience shows that there are few agronomic problems in the crop rotations for cattle and dairy farming, whereas there are larger challenges with respect to nutrient supply and weed control in arable crop rotations. However, the six-course rotation for the vegetable crop production at Årslev has demonstrated that proper rotations with cereals, grass-clover and catch crops makes it possible

to maintain good production of vegetables, even without the use of animal manures.

Several of the workshop areas were converted to arable crop rotation in 2003 to make it possible to increase research on the agronomic problems in these rotations.

Results from long-term experiments

Grazing intensity and residual effects of pastures

Results from experiments with grazing intensity and residual effects of pastures have shown that the huge N-pool in grazed grassland mineralised upon cultivation presents a potential environmental hazard. Using good management practices (spring ploughing and catch crops), the release of N from three-year-old grasslands gave a considerable residual effect for two years after ploughing with relatively little nitrate leaching. A further improvement of N use efficiency requires more consideration of management during grazing.

Table 1. Dairy farm crop rotation in the nutrient cycling experiment at Foulum, from 2003

Field	Crop	Manure treatments (kg N/ha)
1	Spring barley, under-sown grass-clover	1. Slurry, 60 N
2	1st year grass-clover	2. Slurry, 120 N
3	2nd year grass-clover	3. None[3]
4	Spring barley[1] + catch crop	4. Deep litter, 120 N
5	Spring oats + catch crop	
6	Silage maize[2] + catch crop	

Previously: [1] barley/pea whole-crop silage, [2] fodder beets without catch crop, [3] 360 kg N/ha in deep litter

Experiments on grazed grasslands have shown considerably higher N leaching from pure grass stands than from grass-clover mixtures, which indicate larger buffering capacities of the grass-clover leys. This hypothesis has been confirmed from results of an experiment on nutrient management in crop rotations in organic dairy farming. This experiment involved varying rates and types of animal manure, and

the results only gave small differences in production and N leaching between treatments, indicating that grass-clover pastures also here played a stabilising role (Table 1).

Demonstration and communication

Field days have been held at all experimental units, and additionally, a number of farmer groups and other guests have visited the workshop units. Results have also been communicated through other meetings and through several media, including magazines, radio, TV and other electronic media (including targeted web sites). Every year, a three-day seminar has been held at one of the experimental units, primarily targeted for advisors in organic farming. Participants in this course have expressed their great satisfaction with this arrangement. Many of the demonstrations and communication activities have been organised in collaboration with the DARCOF secretariat. Finally, the experiences from the research activities have been communicated on the website: www.okologgen.dk.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/iv1.html
and the internet-archive: www.orgprints.org

Healthy seed for organic production of cereals and legumes

Seed-borne diseases can cause serious problems in the production of cereals and legumes. In conventional agriculture, these diseases are intensively controlled by seed treatment, but this is not an option in organic agriculture.

The threshold levels used today are developed under the presumption that pesticides can be used in case of later disease development in the crop, but no experiments have been made to confirm if the same threshold levels apply under organic farming practice. The project has investigated these thresholds in field trials for diseases in peas and small grain cereals and evaluated them for use under organic farming conditions.

Threshold for seed borne diseases

The results from the project have shown that most threshold levels used in the conventional agriculture generally are practicable in the organic system as well. However, in two important areas, the project suggests a revision. For peas, the project proposes maintaining the recommended threshold levels of max 5% seed with *Ascochyta* in pea seeds and 10% seed with *Ascochyta* in whole-crop peas, but it is recommended that the threshold level should be extended to max 20% seed with Ascochyta if a lack of seed should occur. In the case of lack of seed, it must be considered whether the variety is usable as whole-crop or not. For barley, it is recommended that the threshold levels for net blotch (*P. teres*) are based on the variety's level of resistance to the disease. If the variety is fully susceptible to barley net blotch, a threshold level of 5% seed borne is recommended, while 15% infection of *P. teres* is acceptable in moderately resistant varieties and 25% seed borne in resistant varieties. The comparison between seed infection level and tolerance level should be done only after use of the same laboratory methods used during the project or by methods proved equivalent to the used methods.

New diagnostic methods

The classical seed health testing methods still in use in seed health testing today are based on incubation of seed and growth of the pathogens. This process needs time before the pathogens can be observed and identified by staff with good

knowledge of symptoms on seedlings and identification of pathogens on seeds based on morphological characters. In general, the methods are considered slow and dependent in some cases on subjective evaluation of the expression of the diseases. To improve the threshold levels, it is necessary to have new, more precise and uniform methods for seed analysis.

Real-time PCR methods for leaf stripe (*Pyrenophora graminea*), and Fusarium seedling blight (*Fusarium culmorum, F. graminearum, F. avenaceum* and *Microdochium nivale*) have been developed and used for quantification of seed-borne inoculum in natural seed lots. Significant correlations were found between the amount of *P. graminea* DNA and the number of infected seeds determined by the freezing blotter method and the number of infected plants assessed in the greenhouse test for *P. graminea*. However, some large variations among samples were seen. Due to the inherent sources of variability such as the differences in the amount of *P. graminea* DNA between infected seeds in a seed lot, it may be difficult to establish a better relationship between the PCR method and the conventional methods. In practice, the method can be used as a supplement to the freezing blotter test for detection of *P. teres* and *P. graminia* to identify seed lots containing *P. graminea* and thereby to prevent some seed lots for being unnecessarily discarded. Furthermore, an upper and lower limit of *P. graminea* DNA for a seed lot can be established and used to identify the seed lots that with a probability of 95% will have below or above 5% infected seeds. The PCR method is now being used for identifying seed lots with *P. graminea* DNA at the Danish Plant Directorate.

For the seedling blight complex, the correlations between the PCR method and the conventional method (Doyer) were

Common bunt in wheat - dispersal of propagules to healthy plants during harvest

significant, however, with a large amount of variation. The results indicate that the Doyer method and the PCR method predict emergence in the field with approximately the same efficiency. Due to the complex of fungi, which can cause seedling blight, real-time PCR methods for several species have to be developed and therefore it is not straightforward to implement a standardised PCR method for seedling blight.

Regulation and control

To minimise the development of seed-borne diseases and the number of seed lots discarded, control methods have been investigated and evaluated. Focus has been on preventive methods, which minimise the risk of seed infection, seed cleaning and seed drying equipment.

Heat treatment of grain is a known and documented method for control of seed injections in grain. A drum dryer may be used for heat treatment and experiments show that drum dryer heat treatment has a significant effect on some seed-borne diseases, but without effect on other diseases. Net blotch in barley can be reduced without damage to germination rate. Common bunt in wheat may be reduced, but not eliminated. Without damage on germination rate, no effect was seen in control of Fusarium and pea disease.

Most of the Danish barley and wheat varieties have been tested for resistance to leaf stripe (*P. graminea*) and common bunt (*Tilletia tritici*) respectively.

The activities related to leaf stripe resistance testing resulted in updated information regarding the level of leaf stripe resistance of spring barley varieties currently grown in Denmark as well as of older varieties that may be useful as donors in resistance breeding. A number of varieties on the current Danish variety list seem to be capable of preventing severe leaf stripe problems.

The majority of the Danish wheat varieties are susceptible to bunt (*Tilletia tritici*). Only the Swedish variety Stava has proved to be highly resistant and can be grown without getting infected. A few varieties in the resistance test were infected only at a low level despite very severe infection. In triticale, screening of the new varieties has shown that the majority are resistant to bunt. Only a few varieties are attacked but not as much as the most susceptible wheat

Common bunt in spike

varieties. Spring triticale varieties were first tested in 2005 and seem to be completely resistant to bunt. In practice, an attack of even a few per cent will be too much and will lead to rejection of the seeds, but growing varieties with a certain level of resistance will contribute to a general lowering of the infection level. A promising strategy would be to combine varieties with a certain level of resistance with other forms of control and through this achieve a stable and acceptable level of control.

Perspectives

The initiatives taken in this project have contributed to development of a sustainable seed production system for organic agriculture. Experience and recommendations generated in the research can also be used by organic farmers in other countries and in conventional agriculture to reduce the use of seed treatments and other pesticides.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/vi1.html
and the internet-archive:
www.orgprints.org/view/projects__refereed/da2f1.html

Loose smut

Characteristics of spring barley varieties and variety mixtures for organic farming

In organic crop management systems, characteristics of varieties are very important. The reason is that in organic farming, there are not the same possibilities to control diseases and weeds and avoid lack of nutrients, as there are in conventional farming by the use of pesticides and fertilizers. Because of this, it is important to find varieties and variety mixtures for organic farming, which are very effective in nutrient uptake, have good resistance against important diseases and have the ability to suppress weeds.

Based on several years of field trials with 150 varieties, we have shown that:

- choice of variety is as important a factor for grain yield as other factors in the management
- some variety mixtures may yield even the best variety in the mixture when it is grown in pure stand
- grain yield in each variety is strongly dependent upon the interactions between nutrient level, crop rotation and foliar diseases
- foliar diseases occur more than expected in organic farming systems and cause yield reductions

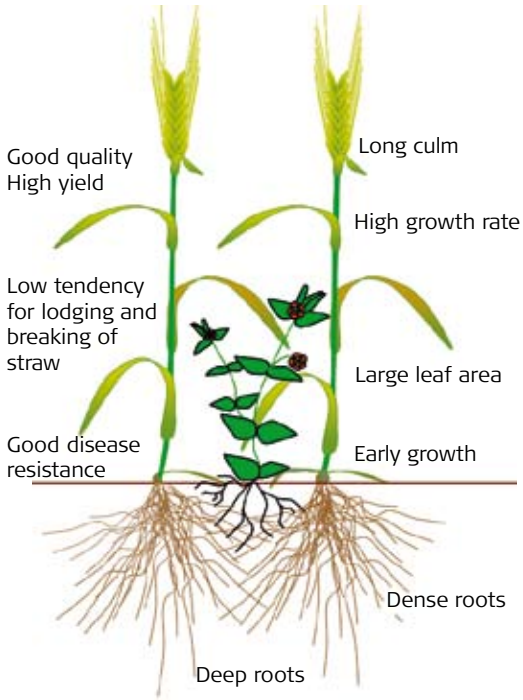
In addition, we have developed:

- a new and better index for describing the ability of each variety to suppress weeds
- a concept for organic variety testing spring barley

Spring barley is the most common grown crop in organic agriculture, covering about 41% of the sown area in spring 2004. Its grain yield depends on the chosen varieties and growth system and varies from year to year. Official information about varieties (VCU-testing) is mainly based on testing under conventional growth conditions, which might give the varieties another ranking than if compared under organic conditions.

The project hypothesis is that a better description of the varietal growth characteristics (Figure 1) and their interaction with cropping systems as well as an increased use of variety mixtures can increase yield and yield stability under organic growth conditions.

Systematic drawing of barley plants in a field indicating some of the variety characteristics of importance for organic farming



This is investigated in the main field trials by comparing growth characteristics of varieties and variety mixtures over years and locations under organic conditions. Further, there have been specific trials with fewer varieties and variety mixtures focusing on interactions between ability of varieties to suppress/tolerate weeds and effect of weed harrowing, interactions between the leaf diseases scald and net blotch, interactions between variety, crop rotation and application of nutrients, and finally the potential application of molecular markers.

Choice of variety and variety testing

The main field trials were mainly carried out on organically grown experimental areas. In addition, some trials were grown under conventional conditions on some of the same localities. In total, there were three growing systems: 1) weed harrowing and reduced application of organic manure, 2) under sown clover grass without application of manure and without weed harrowing and 3) application of fertilizer and chemical weed control (conventional). Application of chemicals to control diseases and pest was not used in any of the trials. Over the years 2002-2005, about 150 varieties (mainly modern ones) and mixtures were grown to test characteristics of special relevance to organic growing systems. The combination of year, locality and growing system are named environments.

About 50 modern varieties that were included in most trials were used in an analysis, which showed that the varieties explained about 30% of the total variation in grain yield when excluding the most extreme growing system without application of manure. The importance of a correct choice of variety was apparent as ranking of many varieties varied between environments.

For all varieties, the pattern of about 100 molecular markers was analysed giving the possibility to relate the yield (and other characteristics) of the varieties with their marker combination. This way, it will be possible to identify pieces of the chromosomes that are responsible for characteristics important for organic farming.

Variety mixtures

A single variety seldom has all preferable traits so the farmer has to choose the traits, which are the most important for the actual growing conditions and market. The choice may be optimized, by combining the best varieties in a variety mixture. In the official variety testing, variety mixtures are seldom tested. However, for several years the standard has been a variety mixture.

Thirteen variety mixtures were included in the main field trials. In general, the grain yield of the mixtures was higher than the average of the single varieties grown in pure stands and some of the mixtures also often yielded the best variety in the mixture grown in pure stand. The grain yield of the mixtures over environments tended to be less variable than for the single varieties. In conclusion, this implies that it

is advantageous to grow variety mixtures. However, until now it has not been possible to predict which characteristics varieties should posses to make the best mixture. Therefore, variety mixtures need to be officially tested in the same way as single varieties.

Competitiveness against weeds

When speaking about varietal competitiveness against weeds, it is important to distinguish between weed suppression (the ability of the variety to suppress weed growth) and tolerance (the ability of variety to produce a stable yield under a given weed pressure). A measure for the estimated weed suppressive ability has been published in relation to the official VCU-testing the last three years. In the project, it has been studied if the existing suppressive index could be more accurate. The results have shown that the suppressive ability of a variety could be estimated more precisely based on measures of culm length, reflectance at early tillering and the leaf angles.

Varieties with very strong suppressive abilities are able to suppress weed cover with 40-55% of the maximal observed weed cover, while varieties with very weak suppressiveness only are able to suppress weed cover with about 10-20%.

Crop rotation and manure application

Six varieties and two variety mixtures were tested in an organic mixed crop rotation. In all varieties/mixtures, we measured positive yield responses to manure application. The effect of manure type and location in the crop rotation varied between the two experimental years. From a plant nutrition point of view, a spring barley variety is suitable for organic crop production if it has a quick development of a large root system. This forms the basis for a large nutrient

uptake. The experiment showed that the cropping conditions including climate, location in the crop rotation and leaf diseases had significant effects on yield and quality of the spring barley varieties.

Disease tolerance

Foliar diseases may play a significant role in both conventional and organic spring barley production. However, there are good possibilities to prevent or delay disease epidemics by choosing varieties and variety mixtures showing sufficient levels of resistance to the diseases, which are most likely to be present in each local area. For this reason, it is of major importance that farmers have access to knowledge about disease resistance traits of potential varieties. In BAR-OF field trials, powdery mildew and net blotch have caused large yield losses, up to 10hkg grain/ha for each disease in susceptible varieties.

The severity of the individual disease in the individual field depends on the level of 'susceptibility' of the variety grown, as well as on the local disease load at the beginning of the growing season, the balance and rate of release of nutrients in the soil, microbial activity and weather conditions. The occurrence of multiple diseases on the same plant may imply increased competition for space, so the presence of one disease at low levels may delay the development of other diseases in the same crop. In addition to a negative effect on yield, foliar diseases have an impact on the quality of the crop, and we observed a trend towards shorter roots as a result of increasing disease severity.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/vi2.html
and the internet-archive: www.orgprints.org

Tools for protection against contamination by GMO

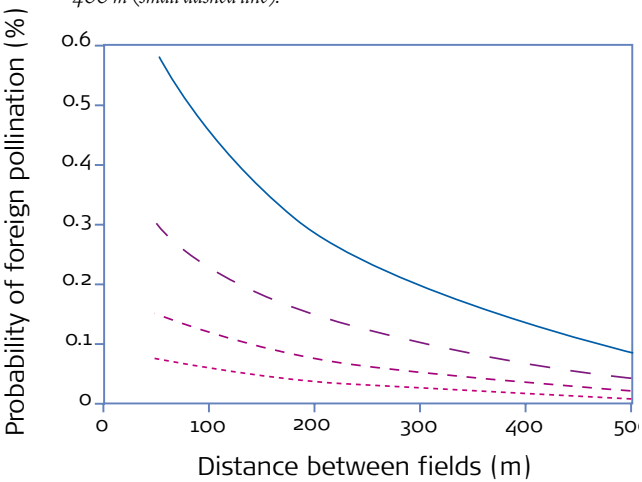
The increased use of genetically modified plants (GMP) and the potential contamination of organic products may have serious consequences to consumer confidence in organic food. Furthermore, GMP constitutes a growing problem to farmers for control and management of field crops.

The TOPRO project has shown that the probability of GMP-dispersal by pollen is less serious for large organic farms than for small farms. The use of a buffer zone (5 m) surrounding the organic field will be able to reduce the GM-pollination by about a third. Furthermore, a statistical model has been developed for detection of the general properties for risk of GMP-dispersal by different wind conditions to individual fields in the landscape. Furthermore, genetic analyses from field trials indicate that harvest methods, seed management after harvest, seed spillage and seed survival in soil should be included more in questions concerning risk of dispersal from GM-varieties to conventional, non-GM varieties.

In Europe and the rest of the world, the use of genetically modified plants (GMP) is increasing in spite of considerable consumer scepticism. Although, GM-crops are not allowed in organic farming, the increasing use of GMP in conventional farming increases the risk of GMP-contamination of organic fields and products. This project therefore aimed at providing measures against adventitious dispersal of GMP by such measures as: isolation distances between GM-fields and organic fields, establishment of safety zones around the organic field, detection and monitoring of GMP dispersal into the field.

The project has sought to fill this need by developing a number of specific tools such as: statistical models for wind dispersal of pollen, a model for probability of pollination between neighbouring fields, guidelines for monitoring of GMP and genetical methods for detection.

Figure 1. The probability of fertilisation by foreign pollen in relation to distance between fields and field width. The widths of the fields shown are 50 m (full line), 100 m (large dashed line), 200 m (medium dashed line) and 400 m (small dashed line).



Prediction of cross-pollination from GM- to non-GM fields of oilseed rape

A mathematical model of pollen dispersal of genetically modified oilseed rape has been developed for use in practical applications. The expected frequency of foreign pollination has been calculated in relation to distance from neighbouring field and field width (Figure 1).

Results from model estimations based on existing data on gene dispersal in oilseed rape indicate that the GM dispersal by pollen to organic fields can primarily be limited by the use of isolation distances. The results also indicate that because of pollen dilution, large fields are better protected from GM pollen dispersal than smaller fields. Analyses show that increasing the width of a recipient oilseed rape field, relative to the pollen donor field, will have a large effect on reducing the average level of fertilisation by foreign pollen within the recipient field. A GM-pollination percentage < 0.1% will be possible if the isolation distance exceed 100 m and the width of the non-GM field is larger than 200 m. The use of a 5 m discarded buffer zone surrounding the non-GM field is expected to reduce GM pollination by approx. 1/3. The Danish committee for co-existence between GM, conventional and organic crops has used the model results for suggesting minimum separation distances between GM and non GM fields of oilseed rape.

Modelling wind dispersal of GM-pollen from oilseed rape and rye

The risk of wind dispersal of GM pollen from oilseed rape and rye to organic fields with the same crop has been tested with an atmospheric computer model. Model simulations

can be used to indicate scenarios, field distributions and wind situations where the risk of GM dispersal to the single organic fields is particularly small or large. The atmospheric model uses meteorological data, the flowering period of the crop and the physical parameters of the pollen for calculations of dispersal from and into fields in the landscape.

The model simulations for oilseed rape pollen in three sites and five seasons indicated that wind dispersal of pollen vary much in relation to the variable meteorological conditions from season to season and between sites.

Prediction of GM-contamination

The model has been used for some detailed predictions for a test area in Jutland. Based on information on the distribution of crops in the landscape, scenario-calculations indicate the influence of field distribution in an area with winter rye. In general, the model calculations support the idea that the separation distance between the fields is the most effective parameter for decreasing the relative proportion of GM-pollen in the air over a non-GM field. The distribution of fields in the landscape and the dominant wind direction in the area are, however, also very important parameters for the total transport of pollen.

The study has shown that a detailed picture of the risk of GM-pollen dispersal in the landscape can be obtained from local meteorological data. The atmospheric model tool can be used e.g. for indicating isolation distances for specific areas and field distributions based on the local need. Genetic differences between certified seed and field crop Volunteers from seed spillage by earlier GM-crops and GM-contamination of seed lots may both cause problems to organic farmers. In order to address this issue, a genetic method (ISSR) for detection of adventitious presence of GMP via pollen and seed in seed lots was tested. The method was applied to detection of dispersal routes in the oilseed rape cultivar Canberra.

The study showed that the genetic profile of plants from the field and of seeds from the plants was genetically different and also differed from the original certified seed lot. An analysis indicated that this was mainly caused by the presence of germinated volunteers from earlier seed spillage. Pollen dispersal from a neighbouring field was not significant. However, inhomogeneity in the sown seed lot could not be excluded. This could indicate that the present restrictions are insufficient to meet the requirements for low GM-content when GM-cultivars are marketed.

The conclusions are, that harvest methods, seed handling after harvest, seed spillage and seed survival in soil are processes which should more often be included in assessment of the risk of dispersal of GM cultivars to non-GM fields. Specifically, additional research in the dispersal routes for oilseed rape by the seed and by seed survival in soil would be advisable.

Monitoring of GMP-dispersal

Monitoring should make early detection of dispersal of GMP to organic fields possible in order to reduce or prevent adverse consequences to organic farming. The methods must be focused on detection of dispersal of transgenes from GM- to non-GK fields by pollen, weedy hybrids or adventitious presence in seed lots. The usability of different types of genetic markers and me-thods for detection of GM-dispersal has been examined with suggestions for practical application.

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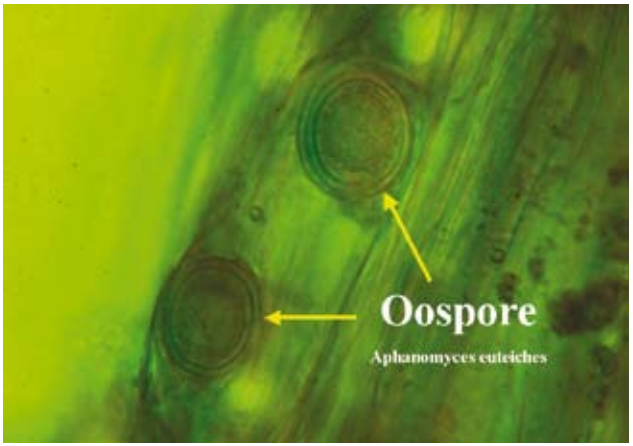
Publications and further information

See the project website:
www.darcof.dk/research/darcofii/vi3.html
and the internet-archive: www.orgprints.org

Grain legumes in organic farming

In organic farming, import of organic soya and other protein sources play an important part of the demand in the Danish organic production of pigs and poultry. To meet the requirement for protein in a feed self-sufficient organic farm with a high proportion of mono-gastric animals, the proportion of grain legumes in rotation should be at least 30% to 50%. Grain legumes can complete cereals in animal feed and are well adapted to Danish growth conditions. Besides being a valuable protein source, these grain legumes benefit the farming system via biological nitrogen fixation and by being a break-crop for cereal diseases. Therefore, limitations, which reduce the maximum ratio of grain legumes crops in the organic rotation as well as their productivity, are direct limitations for the expansion of organic farming.

Soil and seed borne diseases have shown to be one of the biggest treats against sustainable production of grain legumes. In areas with a long tradition for growing pea, Danish surveys have shown that 10-20% of the fields cannot be used for pea production due to high infestation levels of common root rot caused by e.g. *Aphanomyces euteiches*. In such fields, it can take more than 20 years before the infectious oospores of the pathogen have disappeared and do not imply a risk for crop failure. Thus, it is important to avoid and prevent



Resting spores (oospores) of Aphanomyces in pea root, which can survive up to 20 years

propagation of the most important soil and seed borne pathogens in the important grain legume.

In this project, the importance of soil borne diseases in pea, lupine and faba bean will be investigated. Plant resistance is the most efficient control measure and there will be a focus on development of screening methods, which can be implemented in the official variety evaluation system. It is the aim that the results from the project can be transformed into prevention and control strategies against soil borne pathogens in grain legumes

Healthy lupines (left) and wilted lupines caused by Fusarium spp. (right)

Pathogens on pea and lupine in field trials

In three years of field trials from 2002 - 2004, five cultivars of pea, faba bean and lupine, respectively were tested in three dirty plots with natural infested soil coming as a result of an intensive pea-, faba bean- and lupine production. Pea was grown successfully on land heavily infested with lupin pathogenic *Fusarium* spp. and reversely lupin grew well on land heavily infested with the severe pea pathogen *Aphanomyces eutieches*. Varieties of lupin with *Fusarium* wilt resistance and a high level of root rot resistance was identified. Growth of faba bean was apparently not strongly affected by the pea- and lupin pathogens. However, the importance of faba bean for the maintenance and build up of *Fusarium* spp. inoculum with a wider host range is still not clear, but neither lupin nor faba bean was attacked by *A. euteiches*. Pea seems to be the most sensitive legume crop and special precautions are needed to prevent a rapid build up of soil borne pathogens.

Soil testing for root pathogens in organically grown field

A soil test from 20 fields showed that 13 of these fields displayed a root rot disease index (DI) score ranged between 90-100. With an index above 80, it cannot be recommended to grow pea the following 10-20 years. This preliminary result indicates that pea root rot pathogens build up in organic crop rotations where pea has been grown in regularly. There is an urgent need for a survey of the plant health in leguminous crops in organic farming.

Another soil test of an organic and conventional grown field showed, that pea, lupine and vetch were infected by soil borne pathogens in the organic field whereas only the pea was severely damaged in the conventional field. Both soil tests emphasize the urgent need for a thoroughly investigation of the infection level and specificity of soil borne pathogens in organic grown fields.

Implementation of composite cross as a breeding strategy against soil borne diseases

Different breeding methods have worldwide been tested for obtaining disease resistance against A. euteiches. However, the resistance against *A. euteiches* is based on multiple genes, which are very difficult to incorporate in commercial varieties. In this project, we have investigated the possibility of using a composite cross as breeding and selection method for obtaining an increased resistance against soil borne pathogens in general. Screening of breeding lines in the field and in green house showed that the progeny of a composite cross of eight parental lines resulted in a wide genetic variation in resistance against soil borne root pathogens. However, the method is quite time consuming and laborious which unfortunately limits the practical use.

Screening for resistance against common rot root and wilt in pea

In 2004, 40 commercial varieties were tested for resistance against soil borne diseases in a dirty plot naturally infested with A. euteiches. The resistance was scored as yellowing in the field before the naturally senescence of early varieties. Despite a large variation between replicated plots within the same variety, the field trial showed a significant difference in the yellowing between varieties. In a greenhouse study, the same varieties were tested against wilt disease caused by F. oxysporum f.sp. pisi race 1. In this test, 25 varieties out of 39 were characterised as resistance, which emphasise the lack of resistance in many modern commercial varieties. However, even though wilt seems to be wide spread, there is no information available of the prevalence and impact of this pathogen on pea production in Denmark, neither in organic nor in conventional pea production.

Resistance in lupines against soil borne pathogens

Growing lupine continuously, results in a building up of lupine specific pathogens. Field observations have shown that only one season can result in severe root rot and wilt in a susceptible variety the following year due to an increase in Fusarium spp. If lupine becomes wide spread as protein crop, it is necessary to exploit resistant varieties, only.

In 2003 and 2004, 26 lupine varieties were tested on a dirty field naturally infested with Fusarium spp. The trials showed

Screening of resistance in lupine against Fusarium wilt

recommended threshold is a 0-tolerance. However, Danish experiences with *Lupinus angustifolius* have shown that the most resistant varieties can host the pathogen on the seed without showing symptoms in the field crop. Susceptible varieties, on the contrary, can develop severe symptoms in the field at even low levels of seed borne disease.

a wide range in resistance against wilt and root rot ranging from complete wilting to full resistance. Polish and Australian varieties had in general difficulties whereas varieties from Russia, Belarus, Denmark and Poland in general were quite resistant.

Resistance against seed borne anthracnose in lupine

Anthracnose cause by *Colletotricum gloesporioides* is considered as the most important seed borne disease in lupine. In this project, a new screening method in the green house showed to be a feasible tool for identifying resistance at an early growth stages. A screening of 30 varieties showed a large variation from full susceptible to very resistance. The test was verified under field conditions, where four varieties showed to be fully resistant. The exploitation of these types of varieties would prevent the seed borne spread of the disease. The

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/vi4.html
and the internet-archive: www.orgprints.org

Vegetable and Forage Seed – development of an organic, GMO-free seed production

Insufficient supply of organic seed is a potential source for dispersal of genetically modified organisms (GMO) to organic farming systems.

The tunnel production system has the potential to be widely used ensuring availability of a variety of species and cultivars of good quality. In general, the tunnel production being a controlled/confined system could be of major interest in organic seed production in order to maintain coexistence between GM-, conventional non-GM and organic crops. The influence of this source increases by an increased number of release-trials in EU and increased production in conventional agriculture outside EU. Besides the GMO-contamination caused by the use of non-organic seed, it also identifies pollen dispersal and hybridisation to closely related crops or wild species as an important source for contamination. This is higher for cross-pollinated species, which have wind- or insect-pollination.

In vegetable species the supply of organic seed is very limited and the supply of seed from varieties that has been identified as suitable for growing in Denmark is almost non-existing. In a number of forage crops there is coincidence between species in which

- GM-varieties are grown (in agriculture outside EU or in release-trials within EU)
- there is a risk of pollen dispersal and hybridisation
- there is no or insufficient supply of organic seed available.

This project has focussed on the development of an organic vegetable seed production in species that are grown on relatively large areas and where seed production in Denmark is expected to be possible. A number of these species such as carrot and cabbage use to be seed multiplied in Denmark in relatively large quantities. However, the production has been moved to France and Italy, in order to obtain a higher seed quality, since the crop ripens earlier and the prevalence of quality-deteriorating fungi is diminished.

Guidelines for an organic, GM-free seed production are produced in selected vegetable and forage species adapted for production in organic farming in Denmark. In addition the future aspects of maintaing organic, GM-free seed is evaluated.

Identification of fungi on seed

The potential for using image analysis as technique for pathogen infection identification on seed has been screened. Carrot and spinach seed artificially infected with different pathogens have been tested/measured together with pathogen spores deposited on a glass plate. The results are encouraging regarding the possibilities of using image analysis to identify fungal spores on seed. Spectral analyses of spores deposited on a glass plate indicate that the species can be identified using spectra from the spores. However, the amount of data from seeds was not sufficient to build a strong classifier due to focus problems. To test the possibility of creating a classifier that could work in practice more data need to be collected.

Tunnelproduction of organic vegetable seed

From 2000-2005 different experiments with organic seed production of carrot, leek and cauliflower in tunnels has been carried out at DIAS. The tunnel is a 5 m * 50 m lightweight tunnel with a plastic cover and insect-proof netting in the sides as ventilators. In general the temperature in the tunnels rose by 2 °C compared to normal field conditions (Deleuran and Boelt, 2002). Drip irrigation is done at soil surface which leaves the seed heads dry and thereby the risk of development and spreading of fungal diseases is reduced. All weed control is done by hand where needed and larvae's of lady beetles (Coccinella septempunctata) are used to control aphids. Honeybees (Apis mellifera) are used as pollinators. Fertilization is either applied as degassed animal manure or as Binadan. Binadan is a dried and compressed poultry manure. All harvests (harvest of single plants and swathing) are made by hand.

The performance of the harvested seed has been evaluated in the organic crop rotation at Research Centre Årslev.

Carrot

In 2000 the open-pollinated cultivar Berlicum was grown in a tunnel and under normal field conditions using the root to seed system.

In the tunnel 100 - 250 g seeds /m2 (1000 - 2500 kg seeds/ha) were harvested. In the field the seed yield has ranged from 2 - 17 g seeds/m2 (20 -170 kg seeds/ha. In the tunnel production the seed weight ranged from 1,07 - 1,49 g/1000 seeds and the germination percentage of the seeds ranged from 85 - 93 and in the field the seed weight ranged from 1,18 - 1,44 and the germination percentage ranged from 43 - 55 %. In tunnel production seeds from primary and secondary umbels had a higher seed weight and germination percentage than under field production. Seed weight from 'the rest' was higher in field production than in tunnel production, but still the germination percentage was far from satisfactory.

Leek

Trials with leek (cv. Siegfried Frost) from 2002 also compared tunnel production and field production using a root to seed system. Three plant densities have been tested (25x25 cm, 12,5x25 cm and 12,5x12,5 cm) and for each plant density ten plants were cut (selected after maturity). For comparison plants were randomly selected for swathing at three times. In the tunnel each trial has three replicates. In the field there is no replicates and is only performed to give an indication of the potential level. In general this kind of production is not considered realistic under Danish field conditions.

Seed yields in tunnel production ranged from 105 - 273 g/m2 (1050 - 2730 kg/ha) and in the field from 33 - 162 g/m2 (330 - 1620 kg/ha). In both systems nearly no difference was observed between yields from single plant harvest and swathing. The highest yields were harvested from 12,5 x 12,5 cm plant spacing, and the lowest yield from 25 * 25 cm plant spacing. Seed weight and germination percentage in the tunnel ranged from 2,695 - 2,955 g/1000 seeds and 72,3 - 87,7 %.

Cauliflower

Different trials have been performed in respect to hybrid cauliflower seed production in tunnels from 2000-2004 at DIAS. Hybrid seed production is possible but with varying results between plants and years (10 - 49,1 g/plant). In 2001 analysis on seed weight and germination was made. On average of seven harvest times seed weight was 4,21 g/1000 seeds and germination percentage 82.

Discussion and conclusions

Organic seed production in tunnels has a great potential in carrot, leek and hybrid cauliflower. It is possible to harvest good quality seeds with a high germination percentage and seed weight.

Seed yield and germination percentage of especially seeds from the primary and secondary umbels (first positions) of carrot increased considerably in tunnel production compared to field conditions. The carrot seed yield in tunnel production is more than five times higher than from the field production, and 2-5 times higher than yields obtained in earlier years conventional production. In leek high yield and germination percentage can be gained in tunnel production. The plant density 12,5x12,5 had a negative effect on seed weight compared to the other plant densities. Cauliflower production is difficult due to fungal diseases and special emphasis on selection of areas free of *sclerotinia sclerotium* must be made.

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Publications and further information

See the project website:
www.darcof.dk/research/darcofii/vi5.html
and the internet-archive: www.orgprints.org

DARCOF conduct a number of activities intended to develop the research and to exploit the synergy resulting from cooperation between different research environments. In addition to coordination and management of research programmes, activities include knowledge syntheses, research development, international collaboration, research-training and research dissemination.

Knowledge syntheses

In DARCOF, synthesis of knowledge is an important instrument in clarifying particular problems, and for creating a more comprehensive, overall perspective on specific subjects. The latest work has been a knowledge synthesis on organic farming in a global perspective. The British publishers CABI have published the results of the synthesis.

Development of research methodologies and value appraisals

The undertaking of relevant and proactive research requires knowledge about the objectives and values in the system in question; in this case the holistic approach and the objectives and values that guide organic farming and the sustainable development of farming in general. In connection with this work, DARCOF has initiated the Danish discussion on values and principles and engaged in the revision of the founding principles of organic farming of IFOAM that were approved in the autumn of 2005.

European and international collaboration

At European and international level there is an increasing interest in organic and sustainable farming and in recent years, the EU Commission has financed a number of research projects in the area. The research projects in DARCOF II have formed the basis for a relatively large Danish participation in EU research programmes both for the scientists associated with DARCOF and for its secretariat. A list of EU research projects can be found on www.darcof.dk.

Research training and build-up of expertise

A joint research school for organic farming (SOAR) has previously been established in cooperation between The Royal Veterinary and Agricultural University and DARCOF. The aim of the school is to strengthen the quality of research training in organic farming. In the framework of DARCOF II, financial support has been provided for 32 Ph.D. projects in sustainable farming and food production. Please see www.soar.dk for further information

Dissemination

The research in DARCOF II is disseminated on a regular basis. DARCOF has since 1998 published a bi-monthly newsletter, DARCOFenews, which keeps subscribers informed of new research results etc. A free subscription can be obtained via www.darcof.dk.

Research is also continually presented in scientific articles, reports, scientific journals, etc. All the various documents are available via the open internet-archive "Organic Eprints" (www.orgprint.org).