



Midterm Status Report 2002 and Application for Continuation in 2003

For research projects financed by grants from
The Directorate for Food, Fisheries and Agro Business
under the Danish Ministry of Food, Agriculture and Fisheries

1. Research program

Research in organic farming 2000-2005 (DARCOF II)

2. Project title and number

I.6. Cultivation in ridges and mixed cropping - new approaches to organic row
crop production (CARMINA)

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6. Project period (month, year)

Start of project: 09 2000

End of project: 06 2004

7. Midterm description of the project, its results and progress, and application for continuation in 2003

A. Project summary

The aim of the project is to increase the efficacy of row crop production by improving nutrient cycling and growth conditions at the field level and strengthening prophylactic measures against plant pathogens. Ridge tillage and catch crops will manipulate nutrient cycling and growth conditions. Mixed cropping and catch crops will manipulate pathogens and pests. There will be focus on potato but other row crops will be considered too. Crop yield, nitrogen uptake and nitrogen leaching will be used as key success indicators in relation to nutrient cycling and growth conditions. Reduction of late blight (*Phytophthora infestans*) and *Rhizoctonia* stem canker in potato will be used along with tuber yield and quality as key success indicators in relation to prophylactic measures. Ridges will be established in autumn and it will be tested to what extent residual nitrogen and nitrogen from different combinations of organic manures and crop residues can be protected against leaching in winter. Furthermore catch crops and subsoiling will be integrated into the ridge tillage system and an evaluation of the ridge tillage system for organic row crop production will be performed. Interactions between catch crops and *Rhizoctonia* stem canker will be assessed based on the assumption that catch crop holds the possibility to reduce attack. For mixed cropping two types of mixtures will be used: Mixtures of potato varieties and mixtures of potato and faba beans (*Vicia faba*). It will be tested whether mixed cropping can reduce late blight in potatoes and aphid problems in faba bean. By running the project we will be able to verify our assumptions, that ridge tillage and mixed cropping may improve organic row crop production in terms of higher yields and lower impacts on the environment.

Table A.1: Work package list (from application)

No.	Work package title	Participants*	Budget (1.000DKK)	Start	End	Deliverable no(s):
WP1	Protecting nitrogen from leaching in ridge tillage systems	<u>CBH</u> , <u>JPM</u> , <u>JR</u>	1029	1/9 2000	30/6 2004	
WP2	Growing row crops in ridge tillage systems with and without catch crops	<u>CBH</u> , <u>JR</u>	1824	1/9 2000	30/6 2004	
WP3	Growing row crops in ridge tillage systems with and without catch crops with emphasis on stem canker (<i>R. solani</i>) in potato	LB	494	1/9 2001	31/12 2003	
WP4	Improving crop growth by subsoiling in different tillage systems	<u>CBH</u> , <u>JR</u>	229	1/9 2000	30/6 2004	
WP5	Mixing potato varieties	<u>LM</u> , LB	708	1/3 2001	31/12 2002	1
WP6	Mixing potato and faba beans	<u>JPM</u>	416	1/3 2001	30/6 2004	

* Responsible participants are underlined

Objectives and expected achievements

The overall objective of the project is to contribute to better growing systems in organic row crop production resulting in higher yield, better quality and lower nutrient losses.

The project focuses on ridge tillage and mixed cropping as new methods to improve nutrient cycling and growth conditions at the field level and to strengthen prophylactic measures against serious diseases and pests. The project focuses on potatoes as a model crop but other crops are considered as well. In potatoes, late blight and stem canker is selected as model diseases.

The project is approached from an innovative point of view. That means that ridge tillage and mixed cropping are adapted and developed into the context of organic row crop production. Our key question is: If we develop the techniques of ridge tillage and mixed cropping in the context of organic agriculture, how far will it then bring us? By running the project a number of hypotheses concerning ridge tillage and mixed crops are tested:

- 1) Ridge tillage can protect nitrogen from leaching in winter through
 - higher immobilisation of nitrogen
 - reduced percolation through the ridges
- 2) Ridge tillage can increase crop yield through
 - earlier and better establishment of the crop
 - higher mineralisation in spring
 - increased crop nitrogen uptake in the growing season
 - reduced disease severity of *Rhizoctonia* stem canker
- 3) Catch crops can improve yield and quality of potato through
 - improved nutrient cycling in ridge tillage systems
 - reduced disease severity of *Rhizoctonia* stem canker
- 4) Subsoiling can improve crop growth in ridge tillage systems
- 5) Mixing potato varieties can slow down the epidemic development of potato late blight
- 6) Mixing potato and faba beans can reduce attack of late blight in potato and reduce attack of aphids in faba beans and thereby increase yields

C. Midterm results and progress

C.1 Description (summary) of main results and conclusions

Short summary

The aim of the project is to increase the efficacy of row crop production by improving nutrient cycling at the field level and by strengthening prophylactic measures against pathogens via mixed cropping. At the time being, enhanced nutrient cycling shows the best prospects in a practical context and the project has created valuable knowledge concerning the prophylactic measures in a scientific context. The practical prospects, however, seems to be limited.

The project has shown that ridges seem to hold the positive prospects concerning enhanced nutrient cycling. However, the effect of ridges is highly dependent on soil type, timing of setting up ridges, use of catch crops and previous fertilization. Furthermore there are several practical problems that need to be solved.

The positive effects of ridges seems to be caused primarily by their effect on nitrogen. Ridges perform better on loamy soil where there was a strong correlation between a higher level of available nitrogen (ridges 15% higher than ploughing) and a higher potato yield (ridges 23% higher than ploughing). Generally, ridges decrease leaching but may both mobilize and immobilize nitrogen. Timing of ridge establishment relative to catch crops, crop residues and nutrient status of the soil is crucial. To fully understand how to optimise timing of ridge establishment, nitrogen dynamics in ridges have to be studied in detail. This project, however, is first of all aiming to establish an empirical foundation, which may answer the question: Do ridges hold significant prospects concerning improvements of nutrient cycling at the field level, which make it worthwhile to initiate mechanistic based research and technical innovations aiming to optimise ridge tillage? At the current status, the answer is yes, but the project is still young, and a more qualified answer has to wait.

The project has so far shown very positive effects of subsoiling a potato crop in the growing season.

The project shows that the influence of potato variety mixtures on late blight development is insignificant. Even if minor reductions in late blight development have been observed, there have been no positive yield responses. Valuable scientific knowledge about the epidemics of late blight has been achieved. At present, it has not been possible to show positive effects of mixing potato and faba beans as regard to late blight, and it has not been possible to show significant influence of ridges and catch crops on *Rhizoctonia* stem canker. It is, however, probable that the applied experimental and assessment methods concerning *Rhizoctonia* stem canker need sophistication. Several experimental approaches are taken to study how agronomic factors influence *Rhizoctonia* stem canker. Future experiments will be based on artificial soil inoculum and field assessment methods of stem canker will be elaborated.

WP1. Protecting nitrogen from leaching in ridge tillage systems

The potential of ridges to reduce leaching and increase available nitrogen for the subsequent crop is investigated in several experiments.

Field experiments were set up in autumn 2000 at KVL (loamy soil) and St. Jyndevad (sandy soil) to examine the main effects and interactions between soil tillage (ridges and ploughing), timing (early autumn, winter and spring) and catch crops (none, ryegrass and brassicas). Soil samples were taken in November 2000 and May 2001 to determine soil inorganic nitrogen in different soil layers. Conclusions about plant available nitrogen and leaching potential are based on these measurements.

At KVL ridges increased plant available nitrogen with 14.8% compared with ploughing, however, the effect was highly dependent on timing and use of catch crops. The most effective way to reduce leaching was to establish ridges after a ryegrass catch crop in late autumn. If catch crops were not used, ridges established in early autumn protected nitrogen from leaching better than all other treatments. Ridges, however, may also increase nitrogen leaching. Ridges established in early autumn should not be tilted in late autumn and then re-established in order to control weeds. Tilting and reestablishment of ridges caused a bad timing of soil nitrogen mineralization and thereby increased leaching. The analysis of soil samples from St. Jyndevad is not yet concluded. Both experiments have been repeated in 2001-2002, but results are not available yet.

An experiment with bromide used as a tracer was carried out to simulate nitrate transport in ridges. The experiment demonstrated that bromide was more protected in the middle of the ridge than on the side of the ridge or in the furrow. Under normal conditions leaching below the furrow was 104% higher than below the ridge, but if the furrow was compacted due to traffic leaching below the furrow was only 18% higher than below the ridge.

A lysimeter experiment was conducted in 2001-2002 to get direct measurements of leaching associated with ridges and ploughing as primary soil tillage. Inorganic nitrogen from lysimeter leachate during winter 2001-2002 has not yet been analysed. However, yield of a subsequent barley crop was 17.0% higher after ridges ($P < 0.001$). The yield gain was dependent on soil type and the leaching potential of soil. Ridges show better results on loamy soil than on sandy soil and they show better results on soils, which have been heavily fertilized previously. The experiment will be repeated in 2002-2003.

WP2: Growing row crops in ridge tillage systems with and without catch crops

The potential of ridges to improve row crop production is investigated in four field experiments and three pilot studies.

Two field experiments were set up in autumn 2000 at KVL and St. Jyndevad to examine the main effects and interactions between soil tillage (ridges and ploughing), timing (early autumn, winter and spring) and catch crops (ryegrass and brassicas) on the yield and quality of potato in 2001. Both experiments have been repeated, but results are not available yet.

In 2001 there were significant differences between the loamy (KVL) and sandy soil (St. Jyndevad) as regard to treatment effects. At St. Jyndevad catch crops were of major importance whereas soil tillage was of major importance at KVL.

At KVL ridges increased total yield with 23% ($P < 0.05$) and commercial yield with 27% ($P < 0.01$) compared with ploughing but the effect was highly dependent on timing and frequency of tillage and use of catch crops. The highest total yield and commercial yield was obtained if brassicas were sown as a catch crop on ridges set up in early autumn. If catch crops were not used ridges set up in autumn also gave the highest total yield and commercial yield. A strong correlation between plant available nitrogen measured in WP1 and yield was found. If the yield analysis was corrected for available nitrogen no effect of tillage was found. It is therefore concluded that the effect of ridges on potato yield can be solely ascribed to the effect of ridges on available nitrogen.

At St. Jyndevad there was no main effect of tillage, but strong interactions between timing and frequency of tillage and use of catch crops. It was important to crop yield that primary soil tillage was conducted in winter or spring and not in autumn. Under sown ryegrass was a better catch crop than a mixture of brassicas established after harvest of a cereal. Without catch crops ridges established in early autumn was better than ploughing. Ridges established in early autumn should not be tilted in winter and then re-established in order to control weeds.

To investigate the effect of ridge size and placement of animal manure a field experiment with sugar beets was established at KVL in autumn 2000. Animal manure was either placed in strings and incorporated in ridges (50 cm and 75 apart) or broadcasted at the surface before ridging. The experiment showed the importance of deep incorporation of farmyard manure to avoid that manure is harrowed up to soil surface in spring. Ridge tillage resulted in poor seedbed quality in 2001 due to shallow incorporation of manure. The experiment has been replicated in 2001-2002 with a more powerful ridger which succeeded in placing the manure deep enough to avoid problems with a poor seedbed the following spring.

Ridges have not been superior to ploughing in sugar beets until now, and there have been no effect of placing the farmyard manure. Distance between ridges and the subsequent rows of sugar beets was important. Sugar beets at 50 cm row spacing yielded 17%-23% more than sugar beet at 75 cm row spacings ($P < 0.05$).

Three pilot studies with incorporation of clovergrass in ridges and cereals established on ridges has been conducted to achieve answer to some practical questions about the ridge tillage system. The studies showed that clovergrass incorporated in ridges in autumn strongly reduced yield of winter rye and oats as compared

with spring ploughing of clover-grass. Increased leaching from decomposed clover-grass in ridges most likely caused this. The pilot studies also showed that seedbed preparation in ridge tillage need to be further improved. Yield of rye and oats were reduced when sown on ridges compared with sowing in a flat seedbed. The pilot studies will not be repeated.

WP3: Growing row crops in ridge tillage systems with and without catch crops with emphasis on *Rhizoctonia* stem canker in potato

The necessity of producing large quantities of artificial inoculum of *R. solani* (*Thanatephorus cucumeris*) for the field experiments required laboratory studies to find a suitable method for producing large quantities of artificial inoculum (at low costs). Several growth media (infected tubers, mixture of wheat bran and saw dust, potato dextrose agar and malt extract agar) and containers (sterile glass bottles and plastic bags) were included in this study. In a field experiment, the different inoculum types were tested for their ability to cause *Rhizoctonia* stem canker on potato. The results showed large differences in disease severity between inoculum types. Sclerotia produced on malt extract agar gave significantly higher level of disease severity. Infected tubers with sclerotia were also tested, but the seedborne inoculum did not result in disease. In conclusion, artificial inoculum produced on malt extract agar was chosen in field experiments with artificial soil borne inoculum.

It has been investigated how soil tillage, manure and catch crops influence the occurrence of *Rhizoctonia* stem canker in the existing field trials in WP2 at St. Jyndevad. There was a natural disease pressure of *Rhizoctonia* stem canker on the potato plants in 2001 and artificial inoculation was not used. The experiment showed no main effects of manure, soil tillage or catch crop on disease severity, but there was a significant interaction between manure, soil tillage and catch crop. For the highest level of deep litter, the disease level was markedly reduced in ridges established without catch crops. Further statistical analysis will be carried to investigate stochastic and systematic variation in disease incidence in the field experiment.

The field experiments have shown that different methods to assess *Rhizoctonia* stem canker (disease severity, disease index and number of death stems) give different results. This result, will an issue of further studies.

The field experiment was replicated in 2002. This year, however, the natural level of infestation of *R. solani* was very low and it was not possible to study the impacts of tillage, manure and catch crops. In consequence, a field experiment with artificial inoculum was set up at Flakkebjerg august 2002.

WP4. Improving crop growth by subsoiling in different tillage systems

Field experiments in potatoes have been carried out to investigate the interactions between soil tillage (ridge tillage versus ploughing), irrigation (fully versus half irrigated) and subsoiling in the growing season when 10% of the potato plants have emerged. No significant interactions have been found, but a significant yield increase due to subsoiling was found in 2001. Subsoiling increased total yield from 272 hkg/ha to 286 hkg/ha ($P < 0.05$) and commercial yield from 101 hkg/ha to 150 hkg/ha ($P < 0.001$). A reason for the extra yield increase of commercial potatoes (49%) could be that the subsoiler is pruning the potato plants so that fewer underground stalks and thereby bigger potatoes are developed. Harvest data from 2002 is not yet available.

A permanent field experiment has been established at KVL in spring 2001. Before crop establishment plots were a) totally loosened to a depth of 90 cm by digging, b) subsoiled with a commercial subsoiler and c) untreated with respect to subsoiling. In 2001 and 2002 there was found positive correlations between loose soil and plant growth in spring barley and winter rapeseed. Totally loosened soil stimulated plant growth the most.

WP5: Mixing potato varieties

The influence of potato variety mixtures on late blight development was studied in two field experiments at research stations at St. Jyndevad and Borris in 2001 and in 2002. Four varieties (Kuras, Danva, Oleva, Producent) were grown in pure stands and the 4-way mixture in 24x24 m plots in 2001. Experience from detailed studies in 2001 allowed for a reduction in the size of plots of the varieties in pure stands, which were reduced to 12x10.5 m in 2002. At both stations in both years, late blight severity was assessed weekly in 4 -16 subdivisions of every plot depending on plot size. The field trial at St. Jyndevad was selected for more detailed studies, - in 2001, including late blight severity assessments in 25 subplots per plot and foci development, and in 2002, assessments of disease on individual randomly selected plants (Kuras, Oleva) and by remote sensing. At harvest, tuber yield of subplots was determined, and approx 3 weeks later the percent late blight infected tubers was determined. The analysis of the data shows a slightly lower disease level in three of the four trials on infected stem and leaf tissue, but only a significant lower disease level in one out of the four trials (highest reduction 13%). The rate of disease development, measured as the 'apparent infection rate' is significantly reduced in mixtures for all trials. The disease reduction on leaf and stem tissue in mixtures is, however, very small and is not reflected in the tuber yield or in the amount of blight infected tubers. It is concluded that potato variety mixtures can delay an epidemic of potato late blight slightly, and that the tuber yield equals the mean of the component varieties. A high amount of useful data was obtained. The different detailed assessment methods secured a high value of data and set down a method for future studies. The results have shown that airborne diseases in relatively large plants such as potato can be reduced. Finally, it should also be emphasized that the experimental design used in this study gives strong evidence to say that mixing the potato varieties used in practical farming today do not improve control of late blight considerably.

WP6: Mixing potato and faba beans

Field experiments have been conducted with inter-cropping of potatoes and faba bean with 4 rows of each crop in alternating order to delay late blight development. In 2001 and 2002 mixtures have contributed with minor reductions of late blight without any influence on crop yield. In order to investigate the effect of the row direction the rows have been oriented both north-south and east-west in large 24 x 24 m plots. Reference plots with potatoes and faba beans in pure stands have been established for comparison in a randomised block design. In order to investigate in detail the effect of the intercropping system and row direction the establishment and spread of blight infections in the plots have been carefully observed and mapped. Likewise the attacks of aphids on faba beans have been recorded. Results show no clear differences on blight infection or yield between the treatments. Aphid attacks in the faba beans has been insignificant and therefore no difference between treatments could be observed.

C.2 Fulfilment of deliverables and milestones

WP1 Protecting nitrogen from leaching in ridge tillage systems	Time schedule according to application	Deviations, if any*
Deliverables		
1. Evaluation of ridges set up in autumn as an alternative to autumn ploughing for reducing nitrate leaching 2. Paper in international journal on the effects of shape, size and orientation of ridges 3. Paper in international journal on the effects of timing of different soil tillage operations and placement of crop residues/animal manure 4. Paper in popular magazine summarising the results in this workpackage 5. Paper in popular magazine describing a guideline for setting up ridges in autumn		
Milestones		
1. Field experiments finished	09 2003	
2. The effects of shape, size and orientation of ridges has been determined	11 2003	
3. The effects of type and placement of crop residues and animal manure has been determined	11 2003	
4. The effects of timing of setting up ridges has been determined	11 2003	
5. The effects of growing catch crops on ridges has been determined	11 2003	
6. Final evaluation of ridge tillage as an alternative to mouldboard ploughing for reducing nitrate leaching	06 2004	
7. Papers have been written	06 2004	

* *Deviations are to be further discussed at C3*

WP2: Growing row crops in ridge tillage systems with and without catch crops		Deviations, if any*
Deliverables		
1. Evaluation of ridge tillage for organic row crop production 2. Evaluation of the interaction between tillage system and catch crops 3. Evaluation of the effects of ridge tillage and catch crops on stem canker 4. Evaluation of the effects of soil tillage and type/timing of animal manure on potato yield and quality 5. Paper(s) in international journal(s) on the ridge tillage system for organic row crop production 6. Paper in international journal on the effects of soil tillage and timing/type of animal manure on potato yield and quality 7. Several papers in popular magazines describing the progression and results of this workpackage		
Milestones		

1. Field experiments finished	09 2003	
2. The performance of tillage systems based on ploughing and ridges with and without catch crops has been determined	11 2003	
3. The effects of soil tillage and timing/type of animal manure has been determined	11 2003	
4. The energy consumption and economy of ridge tillage for organic row crop production has been determined	02 2004	
5. Final evaluation of ridge tillage for organic row crop production	06 2004	
6. Papers have been written	06 2004	

* Deviations are to be further discussed at D

WP3: Growing row crops in ridge tillage systems with and without catch crops with emphasis on <i>Rhizoctonia</i> stem canker in potato	Time schedule according to application	Deviations, if any*
Deliverables		
1. Evaluation of ridge tillage with organic soil amendments on <i>Rhizoctonia</i> stem canker		
2. Evaluation of the importance of soil-borne inoculum in ridge tillage with organic amendments.		
3. Paper in international journal on catch crops in a ridge tillage system with emphasis on <i>Rhizoctonia</i> stem canker in potato.		
4. Paper in popular magazine describing a guideline for Danish farmers for using organic soil amendments in organic potato production with emphasis on the control of <i>Rhizoctonia</i> stem canker.		
Milestones		
1. Methods have been developed for producing large amount of artificial inoculum of <i>R. solani</i> . Several growth media and containers have been investigated (Primo 2001)	05 2001	
2. The effect of manure, soil tillage, timing and catch crops on occurrence of <i>Rhizoctonia</i> stem canker has been studied in the field trial under WP2 at St. Jyndevad (Medio 2001).	06 2001	
3. Field experiment has been conducted at Flakkebjerg to test the effect of the different inoculum types (Medio 2001).	07 2001	
4. The effect of manure, soil tillage, timing and catch crops on occurrence of <i>Rhizoctonia</i> stem canker has been studied once more in the field trial under WP2 at St. Jyndevad (Medio 2002).	06 2002	
5. Artificial inoculation with <i>R. solani</i> of field experiment at Flakkebjerg and sowing of catch crops and establishment of ridge tillage systems have been performed (Medio 2002).	08 2002	This is a new experiment
6. Healthy seed tubers have been planted in the field experiment at Flakkebjerg (Primo 2003).	05 2003	Continuation of the new experiment

7. The disease severity of <i>Rhizoctonia</i> stem canker has been scored and field experiment at Flakkebjerg finished (Medio 2003)	07 2003	Termination of the new experiment
8. Papers have been written (Ultimo 2003)	12 2003	

* Deviations are to be further discussed in D

WP4: Improving crop growth by subsoiling in different tillage systems		Deviations, if any*
Deliverables		
1. Evaluation of subsoiling for potato production in ridge tillage systems		
2. Paper in international journal on the effects of subsoiling on potato yield and quality in different tillage systems.		
3. Paper in popular magazine summarising the results in this workpackage		
Milestones		
1. Field experiment finished	07 2003	
2. The effects of subsoiling on potato yield and quality in different tillage systems have been determined (12 2003	
3. Papers have been written	06 2004	

* Deviations are to be further discussed at D

WP5: Mixing potato varieties		Deviations, if any*
Deliverables		
1. Evaluation of the efficacy of using potato mixtures as a late blight control measure in organic grown potatoes in Denmark		
2. Paper in international journal on the effect of potato mixtures on late blight development		
3. 2 Papers in popular magazines or proceedings		
Milestones		
1. A method for assessing late blight in potato mixtures has been developed	07 2001	Achieved
2. First years field trials have been analysed and possible adjustments of design of the field trials can be decided	12 2001	Achieved
3. AUDPC measurements in two years field trials completed	11 2002	Achieved
4. The efficacy of organic grown potato mixtures as a late blight control measure is determined	12 2002	Achieved

* Deviations are to be further discussed at D

WP6: Mixing potato and faba beans		Deviations, if any*
Deliverables		
1. Evaluation of intercropping of potatoes and faba bean as a growing system		
2. Evaluation of the possibility to reduce attack of late blight in potatoes using intercropping		
3. Evaluation of the possibility to reduce colonisation of aphids in faba bean using intercropping		
4. Paper in international journal describing the potato faba bean intercropping and effect on pests and diseases.		
5. Paper in popular magazine summarising the results of this workpackage		
Milestones		
1. Field experiments finished	12 2003	
2. Influence of intercropping on potato late blight epidemiology has been determined	12 2003	
3. Influence of intercropping on aphid abundance in faba bean has been determined	12 2003	
4. Final evaluation of possibilities and perspectives of potato intercropping with faba bean	06 2004	
5. Papers have been written	06 2004	

* Deviations are to be further discussed at D

D. Description of deviations and subsequent adjustments of plans

The project is based on an innovative approach. This means that running adjustments is a part of the plans. A balance is attempted between running adjustments and repetition of experiments in at least two years to ensure the possibilities of publication. As it is very expensive, and more expensive than expected, to run field experiment with potatoes and sugar beets, some experimental plans in WP1 and WP2 have to be reduced. The decision will be taken after results from 2002 have been analysed.

The greatest modifications in plans have been in WP3 (Growing row crops in ridge tillage systems with and without catch crops with emphasis on *Rhizoctonia* stem canker in potato). The original experimental approach was to use soil-borne inoculum (seeds with black scurf) in field experiments. As described in C.1, however, a field experiment showed no diseased plants after infected tubers with black scurf. Furthermore, it is costly to carry out field experiments with artificial inoculum. In consequence, it was decided to assess the natural occurring infections of *R. solani* in the field experiments in WP2 at St. Jynde vad. Fortunately, there was a high infestation level of *R. solani* in 2001, which made it possible to test the effect of the full ridge tillage system on *Rhizoctonia* stem canker, but it was not possible to repeat the experiments due to low natural infestations in 2002. Therefore, it has been decided to establish a field experiment with artificial inoculum despite the high costs to examine the main effects of soil tillage and catch crops on the incidence of *Rhizoctonia* stem canker. Potatoes will be planted in spring 2003.

E. Project publications and other products

1. Articles in international, scientific journals with review procedures

Kromann, P. L Bødker, T. Koch & L. Munk. Do potato variety mixtures reduce late blight development? (in preparation)

2. Papers presented at congresses, symposiums, etc.

Henriksen, C. B. (2000): Er kamme et alternativ til pløjning. Presentation, Det Kgl. Danske Landhusholdningsselskabs Akademiråds efterårsseminar, Foulum, Denmark, 8/11 2000.

Rasmussen, J. & Henriksen, C.B. (2002): Kamdyrkning (drill) – i stedet for pløjning. Presentation, Den nasjonale kongres for økologisk jordbrug, Hamar, Norway 21/2-22/2 2002 (www.agsci.kvl.dk/~jeraj5/Norge.pdf)

Rasmussen, J. (2000): Alternative jordbearbejdningsmetoder. LØJ-seminar om jordbearbejdnings og jordfrugtbarhed. Byholm Landbrugsskole, 19/9 2000 (www.agsci.kvl.dk/~jeraj5/jordbearb_pr.PDF)

Rasmussen, J. & C.B. Henriksen (2000): Jordløsninger - er det svaret? Økologi Kongres 2000. Kongresbilag: 26-27 (www.agsci.kvl.dk/~jeraj5/svaret.PDF)

3. Reports, articles in agricultural journals, etc.

Henriksen, C. B. (2000): Kamme som alternativ til pløjning. Tidsskrift for Landøkonomi Nr. 4(187): 311-314

Henriksen, C.B. & Rasmussen, J. (2002): Kamdyrkning (drill) – et økologisk alternativ. I Cottis T. (ed): Den nasjonale kongres for økologisk jordbrug, Rapport nr. 3, 61-68. (http://fulltekst.bibsys.no/hihm/rapport/2002/03/rapp03_2002.pdf)

Thomsen, H.C. (2001) Kan hestebønner forsinke skimmelangreb. Kartoffelproduktion 29 (4): 6-7

4. Oral presentations, public meetings, field days, etc.

Henriksen, C.B. FØJO Field day at Jyndevad with presentation of Carmina experiments at Jyndevad. 20/6 2001

Henriksen, C.B. Field day at KVL with presentation of experiment with ridge cultivation of maize for visitors from Asia, 22/6 2001

Henriksen, C.B. Field days at KVL with presentation of experiment with ridge cultivation of maize for visitors from Africa, 29/6 2001

Henriksen, C.B Field day at KVL with presentation of experiment with deep litter and fodder beet for the Technical School of Slagelse. 29/8 2001

Henriksen, C.B. Field day at KVL with presentation of experiments with ridge cultivation for visitors from Asia, 31/5 2002

Henriksen, C.B. FØJO Field day at KVL with presentation of Carmina experiments at KVL, 6/6 2002

Henriksen C.B., Thomsen H.C. (2002): CARMINA – Kamme, dybe jordløsninger samt sorts- og artsblandinger i økologisk dyrkning af rækkeafgrøder. Feltdage ved økologiske forsøgsarealer 17.-19. juni 2002.

Henriksen, C.B. FØJO Field day at Jyndeved with presentation of ridge tillage and sub-soiling experiments at Jyndeved. 20/6 2002

Munk, L. (2002). Variety mixtures in controlling disease resistance. Internal seminar, KVL

Mølgaard. J.P FØJO Field day at Jyndeved with presentation of Carmina experiments at Jyndeved. 20/6 2001

Rasmussen, J. (2001): Alternativer til pløjning. Kursus arrangeret af Sjællandske Familiebrug, Roskilde 10/10 2001 (:www.agsci.kvl.dk/~jeraj5/jordbearb_ros01.pdf)

Rasmussen, J. Field day at Jyndeved with presentation of experiments with mixing potato and faba beans at Jyndeved. 20/6 2002

Thomsen, H.C. 15-20 groups (more than 200 people) have visited the CARMINA-experiments at St. Jyndeved

F. Scientific education

Grossmann, F. (2002): Forbedring af jordkvaliteten efter jordpakning. Speciale i Økologisk Jordbrug, Institut for Jordbrugsvidenskab, KVL.

Kromann, P. & T. Koch (2002): Blandingskulturer til bekæmpelse af kartoffelskimmel. Speciale i Plantepatologi. Institut for Plantebiologi, KVL

Mathiasen, K. (2002): Effekter af midlertidige kamme på temperatur, vandindhold, volumenvægt og fremspiring i såbed til majs. Speciale i Økologisk Jordbrug, Institut for Jordbrugsvidenskab, KVL.

G. National and international cooperation

H. Critical reflection on the project

General reflections for the project as a whole

The project is running very close to the initial intensions described in the application. It is, however, disappointing that the project have not shown any strengthening of the possibilities to control late blight by mixing potato varieties and mixing potato and faba

beans. This disappointment is counterbalanced by solid data on epidemics of late blight and the satisfaction with the fact, that this project has very good data showing that mixed cropping has not reduced or delayed late blight enough to increase yield. The data is able to support that plot size was big enough to make conclusion relevant in a practical context.

It was expected that catch crops were able to reduce *Rhizoctonia* stem canker. It has, however, not been able to verify this assumption. At present, it is unknown whether this is due to methodological problems. It is difficult to use natural infestation in controlled experiments and it is very expensive to use artificial inoculum. It was expected, that infected seed potatoes could be used in the experiment, but primary results showed that infected seed potatoes did not result in diseased plants. This fact has complicated the experimental work and increased the cost. The advantage, however, is that this project will probably be able to answer methodological questions, which is important in with respect to field experiments aiming to quantify the effects of agronomic factors on *Rhizoctonia* stem canker.

This project has shown significant differences in prospect of ridge tillage on different soil types. At present, the best results from a scientific point of view have been found on loamy soil with 15-20% clay. It requires, however, good workmanship and better machinery to establish ridges on wet soils with relatively high clay content in late autumn. It also requires new implements to establish crops on ridges.

Reflections on ridges tillage

There have been considerations about the experimental designs. In the beginning, the ridge project was more focussed on experiments that were primarily designed to compare tillage systems. Since there are differences between the optimal timing of ridge tillage and ploughing (ploughing is not performed immediately after harvest and ridges are not set up in spring) the optimal catch crop is also different (under-sown ryegrass is not suitable when ridges are established shortly after harvest of cereals). This makes it difficult to fully evaluate the individual effects of tillage, timing and catch crop. Therefore, we have both expanded and simplified our experiments. The field experiment with ridge tillage and catch crops at KVL have been expanded to become a full factorial experiment even though some treatments are expected to be irrelevant in a practical context.

Experiments with maize have demonstrated difficulties with crop establishment on ridges. With current equipment it has not been possible to establish good seedbed on the top of ridges. Furthermore, it has been necessary to discontinue an experiment because birds preferred to eat seeds and seedlings on ridges. Detailed studies on the relationship between temperature, soil water content and maize growth in early growth stages were more or less in vain due to low germination percentage of maize on ridges due to a desiccated seedbed. Brassica catch crops on ridges have also been difficult to establish. The catch crop is almost solely established in the furrows between ridges. This may not have a negative impact on leaching but a better establishment would stabilize the soil, increase soil porosity and secure competition against weeds. This emphasises the need to develop a drill for ridges.

Our experiments show that ridges established in autumn increase available nitrogen if they are established in a ryegrass catch crop. This, however, increases the risk of soil compaction in the furrow if soil is wet. At the same time ridge-incorporated ryegrass is not fully decomposed in spring and may decrease seedbed quality in spring.

We have found that repeated harrowing of ridges in autumn has been sufficient to control weeds. In this way a full re-establishment of ridges which leads to increased leaching can be avoided. However further studies are needed to evaluate if harrowing is sufficient to control perennial weeds in a permanent ridge tillage system

In all field experiments ridge tillage is used as a one-year treatment in an exist-

ing arablesystem based on ploughing. Ridges are set up after spring barley at KVL and after winter rye at St. Jynde vad. The results have to be interpreted in this context. Both timing of setting up ridges, weed pressure and residual soil nitrogen would be different if the experiments had been established in a vegetable cropping system. We have chosen to integrate ridges into an arable cropping system with cereals and potatoes to reduce experimental complexity and costs.

The project aims to create a solid basis for evaluating the potential of ridge tillage for organic row crop production. Until now we have demonstrated that ridge tillage holds positive prospects given that several technical problems are solved. By continuing our experiments we will be able to optimize ridge tillage for organic row crop production in arable systems and provide a basis for further studies on ridge tillage in other growing systems.

Reflections on mixing potato varieties

The experiments were conducted according to the plans described in the application. The strong point of this study is its design to give direct answers to farmers today. The varieties chosen, and the plot sizes, are directly comparable to farm practise. The experiments were carried out at two stations, which provided good solid technical assistance, and the cooperation has been excellent. The results of the experiments were to a minor extent hampered by unfavourable weather conditions, especially in 2002. High amounts of rainfall in the early summer of 2002 appeared to result in high levels of nitrogen leaching. The potato crop came to suffer from plant nutrient stress, which might have influenced the effect of the variety mixtures on disease level. Similar experimental constraints of controlling random effects on crop growth appeared in 2001, and there were problems with avoiding unnatural spread of spores due to traffic by the persons assessing the disease. This was taken into account in 2002, where a new assessment plan was followed, and the constraints are not considered to have an impact on the conclusion. These studies have also shown that if more detailed investigations are to be carried out (for instance mechanism studies) then controlled experimental designs as well as optimal environmental conditions are necessary. It is the author's opinion that further research and development of potato mixtures should focus on varieties with a higher level of resistance, and if available preferably a high degree of combined specific and non-specific resistance. The results illustrated that the mixture effect of varieties with this level of resistance could not uphold an effect reflected on yield. Variety mixtures of the available varieties are therefore not applicable for control of late blight alone, but most be seen in an integrated approach. The concept of using mixtures to control diseases of large row crops in organic farming must be optimised and combined with other practises, before it is fully applicable for practical farming.

8. Budget

A. Account for any change in budgets

B. Budget for the whole project (1.000 DKK)

Total consumption of funds from DARCOF and expected consumption this year and coming years

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	19	24	17	3,5		63,5
Technical personnel	17	15	11	0		43

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	618	797	552	114		2081
Technical personnel	217	213	144	0		574
Other operational costs	425*	545*	272	15		1257
Equipment						
Others (please specify)						
Direct costs	1260	1555	968	129		3912
Indirect costs (20% of direct costs)	252	311	194	26		783
Total	1512	1866	1162	155		4700

Comments: Please see modification in KVL consumption and budget

9. Signatures and stamps

Name	Institute	Date	Signature
Head of project			

Appendix I. Detailed budget

A. Budget for each participating institute (1.000 DKr)

Name of Institute: KVL

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months	15	14	12	2	0	43
Scientific personnel	15	14	12	2	0	0
Technical personnel	0	0	0	0	0	0

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries	471	456	384	64		1375
Scientific personnel	471	456	384	64		1375
Technical personnel	0	0	0	0		0
Other operational costs	213*	327*	195	10		745
Equipment	0	0	0	0		
Others (please specify)						
Direct costs	684	783	579	79		2125
Indirect costs (20% of direct costs)	137	157	116	15		425
Total	821	940	695	94		2550

Comments:

By a mistake invoices for Dkr 105.000 spend in 2001 were not paid before 2002. Therefore, it is kindly requested to transfer expenses Dkr 105.000 (plus overhead) to 2002.

B. Budget for each participating department (1.000 DKK)

Name of Institute and department: DJF

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months	15	17	11	1,5		44,5
Scientific personnel	6	8	5	1,5		20,5
Technical personnel	7	9	6	0		22,0

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries	364	554	312	50		1280
Scientific personnel	147	341	168	50		706
Technical personnel	217	213	144	0		574
Other operational costs	212	218	77	5		512
Equipment						
Others (please specify)						
Direct costs	576	772	389	55		1792
Indirect costs (20% of direct costs)	115	154	78	11		358
Total	691	926	467	66		2150

Comments: