Title: I.6 Cultivation in ridges and mixed cropping – new approaches to organic row crop production

Acronym: CARMINA

Date: 28th of February 2000

1. 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 (*Phytophtora 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 set 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.

2. Research group

Royal Veterinary and Agricultural University (KVL)
Jesper Rasmussen (JR), Associate professor, (Co-ordinator), Department of Agricultural Science
Lisa Munk (LM), Associate professor, Department of Plant Biology
Christian Bugge Henriksen (CBH), Ph.D. student, Department of Agricultural Science

Danish Institute of Agricultural Sciences (DIAS)
Lars Bødker (LB), Senior scientist, Department of Crop Protection
Jens Peter Mølgaard, Scientist, Department of Crop Physiology and Soil Science

The project group represents expertise on 1) soil tillage and weed science (JR+CBH), 2) plant pathology and mixed cropping (LB+LM) and 3) quantitative and qualitative aspects of potato growing (JPM) All areas of expertise include scientists experienced within organic agriculture research. JR + CBH constitute a part of a newly established project group on soil tillage at KVL. JR is experienced in team building.

3. Introduction

Nutrient cycling and prophylactic actions against weeds, pests and diseases are key principles in organic farming. Both principles are practised in several ways. Crop rotation, mixed cropping, catch crops and soil tillage are well-known examples.

In this project, we are aiming to develop and implement new growing practices in organic row crop production. The objective is to increase crop yield and quality by improving nutrient cycling and growth conditions at the field level and diminishing the importance of pests, diseases and weeds. Our focus will be on ridge tillage and mixed cropping. Both methods are well known from other crop types and cropping systems in other parts of the world, but we believe they can be developed and implemented in organic agriculture in Denmark.

Ridge tillage is an alternative soil tillage system without mouldboard ploughing. Instead of ploughing, the soil is left in ridges for the autumn and winter. It is mostly used for conventional maize and soybean production in USA. Ridge tillage has never been implemented in organic farming in Denmark. One reason could be that most organic farmers generally want to avoid none-inversion tillage systems due to weed problems. Another reason could be that the potential advantages of ridge tillage still have to be proven in organic growing systems. Based on a comprehensive literature review and promising results from an ongoing project in Denmark, we suggest that ridge tillage may contribute to a higher yield in organic row crops.
Mixed cropping and intercropping are ways of attempting to restore biological diversity to a cropping system at the field level. Advantages have been shown in several crop systems. Especially, in the tropics and grass-clover mixtures. Row crops in field scale, however, are grown as monocultures in Denmark. This is mainly due to the fact that mixed cropping complicate mechanised field operations. Therefore, we find that the motivation for mixed row crops should be to address recognised problems associated with monocultures.
For mixed cropping we have chosen potato as a model crop, because potato nearly always is attacked by late blight, early attack may reduce crop yield by 50%, and because potato is grown in ridges set up in spring. However, other crops are considered too.

Before it is possible to put new methods like ridge tillage and mixed cropping into practice, a number of practical questions have to be solved. Especially regarding mixed cropping which rises several questions about mechanisation. Our approach is, that new cultivation growing techniques should show promising results in experimental set ups, before technical solutions are developed to meet field scale growing. If ridge tillage and mixed cropping show positive results, as we expect from experiences elsewhere and theoretical considerations, the basis for technical development is created.

4. State of the art

Extension and performance of ridge tillage systems

Ridge tillage is the most common non-inversion tillage system in the cornbelt of USA. Savings on energy and improved farm economy have been demonstrated (Griffith et al. 1990, Reeder 1990, Borin et al. 1997). It is practised in slightly different ways, but usually there are no field operations between harvest and sowing of the subsequent crop. Before sowing the top of the ridges are removed with a ridge scraper and the crop is drilled directly in the middle of the ridge together with fertilisers and pesticides (Hatfield et al. 1998). Thereafter ridges are rebuilt during the growing season and the crop residues are left at the surface after harvest. Alternatively, ridges are not rebuilt until after harvest where crop residues are incorporated into the ridges (Borin and Sartori 1995). If the preceding crop is not a row crop, the ridges are usually established immediately after harvest. It is recommended to use controlled traffic and to rebuild ridges at the same place year after year (Griffith et al. 1990, Tisdall and Hodgson 1990, Hatfield et al. 1998).

Ridge tillage is hardly used in Europe. However, successful experiments with ridge tillage have been carried out in potatoes, chicory salad, early carrots, sugar beets and barley (Spiess 1991, Alblas and Kouwenhoven 1993, Friessleben et al. 1988, Borin and Sartori 1995).

Effects of ridge tillage on soil, crops and weeds

Many field experiments have demonstrated that ridge tillage may increase yields in various crops and reduce the use of fertiliser and pesticides (West et al. 1996, Griffith et al. 1990, Reeder 1990, Fausey 1990, Vyn et al. 1990). This applies not only to row crops but also to cereals and grass (Tisdall and Hodgson 1990).

There are several plausible reasons for yield increases in ridge tillage systems:

Yield increase can be achieved by reduced nutrient losses in autumn and winter due to
- increased immobilisation of inorganic nitrogen
- reduced leaching of inorganic nitrogen

Yield increase can be achieved by improved growing conditions in spring and summer due to
- earlier and better crop establishment
- improved soil structure
- improved soil water storage
- higher mineralisation rate
- improved oxygen supply to plant roots
- reduced disease severity of soil-borne diseases

Documentation of the above cause-relationships will be presented in the following

There are several studies indicating that ridges set up in autumn can improve nitrogen cycling through increased immobilisation and decreased leaching in autumn and winter. Angers et al. (1993) found that soil microbial biomass was 2-3 times higher in fields with ridges than in flat fields. Higher microbial activity in ridges has also been found in an ongoing field experiment in Denmark (Henriksen 1999). If crop residues with a high C/N ratio are incorporated into ridges a higher microbial activity will lead to an increased immobilisation (Hatfield 1998). The actual shape of ridges influence leaching of inorganic nitrogen. To a certain extent, precipitation will pour down the sides of the ridges thereby protecting inorganic nitrogen within the ridges from leaching. An experiment with placement of nitrate and bromide in the middle of ridges demonstrated reduced leaching from ridges compared with flat seedbeds (Hamlett et al. 1990). Leaching from flat seedbeds were 47% for nitrate and 38% for bromide. For the ridges, the corresponding values were 11% and 6%. Similar results have been achieved with placement of fertilisers within the ridges. In a three-year field study with intensive maize production in USA, the loss of nitrogen in drainage water from ridge tillage was 22-31% less than from conventional tillage (Drury et al. 1993).

Ridge tillage has also been found to increase soil temperature and drainage in spring compared to conventional tillage. Among other things this allows for earlier sowing and crop establishment (Griffith et al. 1990, Eckert 1990, Hatfield et al. 1998). Experiments in the Netherlands have shown increased yields of chicory salad and early carrot due to earlier sowing in ridge tillage systems (Alblas and Kouwenhoven 1993). At the same time soil drying in summer can be reduced by ridge tillage. Unger (1994) and Hatfield et al. (1998) have shown that ridge tillage decreases evaporation and improves soil water storage during the growing season.

A comparative study between different tillage systems in USA has shown that ridge tillage with controlled traffic increases aggregate stability, increases soil organic matter and decreases soil bulk density compared to conventional tillage (Jordahl and Karlen 1993). Lower soil bulk density and shorter distance from roots to soil surface in ridges increase the oxygen supply to the plant roots. An increase of up to 52% has been measured in the upper 20 cm in permanent pastures grown on ridges (West and Black 1969). Increased soil temperature improved soil water storage and good soil structure may also work in combination to increase nitrogen mineralisation during the growing season. This has been documented by Clay et al. (1995) who found higher rates of N-mineralisation during the growing season in ridges than in a flat seedbed. The shape, size and orientation of ridges affect soil moisture, radiation absorption and decomposition of organic matter (Sharratt et al. 1992, Ghaffarzadeh et al. 1996) and will also have a large effect on immobilisation/mineralisation of nitrogen. Mathematical models have been made to simulate soil temperature and water and heat transport in ridges with different shapes and sizes (Benjamin et al. 1990, Gupta et al. 1990, Noborio et al. 1996). These models could be used as a tool for constructing optimal ridges under different conditions. An increased mineralisation in spring would be particularly valuable in organic potato production, since the potato crop has a demand for nitrogen in a relatively short period of time. A slow mineralisation and late supply postpones maturation and cause loss of yield and quality due to immature tubers.

It is well known that reduced tillage often increases weed problems. Extensive studies, however, indicate that ridge tillage is one of the ploughing-free soil tillage systems that offer the best feasibility to control weeds (Exner et al. 1996). Using ridge tillage in a crop rotation seems to level out the differences in weed propagation between ridge tillage and conventional tillage based on ploughing (Forcella and Lindstrom 1988). Removal of the top of the ridge prior to sowing works as an initial weed control by destroying germinating seeds (Griffith et al. 1990). Re-building the ridges during the growing season works as a weed control. Additional weed control in the inter-row spaces can be performed with inter-row cultivators. Whether ridge tillage can be succesfully applied for organic row crop production in Denmark need to be assessed.

Use of subsoiling for potato production in ridge tillage systems

In a ridge tillage system without mouldboard ploughing subsoiling may improve crop growth conditions by creating a loose soil. Several experiments and experiences have shown that potatoes may respond positively to subsoiling in autumn. In a Danish study subsoiling gave yield increases for potato in 7 out of 9 cases (Jensen 1971). In a large English study subsoiling gave a significant yield increase of potato by 4,4% on clays and loams, if a high level of fertiliser was used, whereas a similar but non-significant tendency was observed on sands and light loams and on all soil types with low levels of fertiliser (Russel 1956). In a more recent study subsoiling in autumn was shown to increase potato yield by up to 14% (Häge 1996).

Subsoiling in spring before or soon after sowing has been investigated in several experiments. Most experiments indicate positive yield responses to subsoiling (Pierce and Chase 1987, Pierce and Burpee 1995, Sojka et al. 1993, Westerman and Sojka 1996). Several studies indicate interactions between subsoiling and water supply. If water supply is optimal beneficial effects from subsoiling is small or even absent (Ross 1986, Ibrahim and Miller 1989, Parker et al. 1989, Miller and Martin 1990). Promising experiments with subsoiling in the growing season is currently being conducted at KVL.

Use of catch crops for potato production in ridge tillage systems

Catch crops established on ridges in autumn may improve ridge tillage by decreasing nutrient losses during winter. This strategy has been investigated for potatoes grown in ridge tillage systems. Catch crops were sown directly on ridges after harvest of the preceding crop and incorporated into soil with a rotary cultivator in spring. Ridges were rebuilt after sowing the potato crop (Häge 1993, Spiess 1994a). Alternatively, potatoes can be sown directly in the frost-killed catch crop after removing the top of the ridge (Spiess 1994a). Several experiments have demonstrated that catch crops such as oilseed radish or white mustard grown on autumn ridges has the potential to decrease leaching and increase yield (Sholz 1986, Hofmann 1991, Lang 1994, Spiess 1994b). Yield increases up to 16% have been observed compared with conventional spring ridges without catch crops (Spiess 1994b).

The right choice of catch crops in a ridge tillage system may also have a beneficial effect on potato yield by reducing the incidence of potato stem canker (*Rhizoctonia solani*). Next to *Phytophthora infestans* causing late blight in potato, *Rhizoctonia* stem canker is the most important disease in organic potato production. In potato, the plant pathogen *R. solani* causing stem canker is under major influence by the type and amount of organic matter in the soil (Holm 1997, Holm et al. 1999, Scholte and Lootsma 1998) and soil tillage (Holm 1997, Leach et al. 1993). Holm et al. (1999) found severe attack of stem canker after clover grass and a reduced attack after oats as precrop. However, autumn green manure is known to have the ability to suppress *R. solani* in potato. Scholte and Lootsma (1998) found a reduced disease severity when white mustard was combined with application of farm yard manure and oats were grown as a green manure crop. Before introducing a new cropping system using organic amendments to farmers, it is important to study the impact on *Rhizoctonia* stem canker.

Use of potato variety mixtures to reduce late blight in potatoes
Late blight, caused by *Phytophthora infestans,* is the most important disease of both conventional and organic grown potatoes. Yield loss in organic potato production due to late blight is estimated to 35% compared to conventional farming systems, which are based on weekly chemical treatments during the growth season (Anon 1999). If the epidemic can be delayed one week, the prolonged growth of the crop will result in a yield increase of approximately 7 tons pr. ha.

Using potato varieties with resistance to late blight is an environmental safe control strategy. Both monogenic (major, R-genes) and polygenic (quantitative) host resistance are present in potatoes (Crissman and Lizárraga 1999). The monogenic resistance is known to break down within few growing seasons due to selection for virulent pathotypes of *P. infestans*. Therefore, current potato breeding all over the world focuses on resistance based on polygenes. The polygenic resistance is not complete in the reaction to late blight, but it is expected to be durable.

In cereals, it is well known that variety mixtures composed of varieties with different race-specific resistance genes delay the epidemic development of airborne pathogens and stabilise grain yield. (Kølster et al. 1989, Munk 1998, Wolfe and Finckh 1997). For instance, it has been shown that spring barley mixtures reduce powdery mildew severity up to 80 % resulting in a grain yield increase (Kølster et al. 1989). Differences in specific resistance of the components is the most important factor for the mixing effect, but also differences in partial resistance may be beneficial in mixtures (Jeger et al. 1981). The main mechanisms operating in mixtures are spatial distance between identical plants, induced resistance and barrier effects (Chin and Wolfe 1984). In potatoes, preliminary French experiments mixing a susceptible variety with two partially resistant varieties have demonstrated significant benefits in both disease reduction and yield (Andrivon et al. 1999). Anecdotal evidence from both Denmark (Jensen 1998) and UK (Finckh 1999) support these results. More diverse results have been obtained from trials carried out in Ecuador, Peru and USA (Garrett et al. 1998), as the size of the mixing effect seemed to be influenced by the level of inoculum. The effect of a mixture depends on the resistance of the component varieties. In Denmark, a number of potato varieties with different levels of partial resistance are available. Whether these varieties are suitable for mixing to delay development of late blight epidemics need to be assessed.

Use of mixed cropping of potato and faba bean to reduce late blight in potatoes
Mixed cropping of potatoes with other crops represent another potential strategy to reduce late blight in potatoes. Nowadays potatoes are grown in monoculture in Europe, but in the tropics intercropping is widely used and substantially research efforts have been put into developing intercropping systems (Kreul and Trognitz 1993). The emphasis of these studies has been to maximise light utilisation and minimise inter-specific competition (Midmore 1990). However, intercropping also has a large potential for reducing pests and diseases of potatoes through establishment of physical barriers, modification of the microclimate, olfactory effects and habitats for natural enemies (Potts 1990). McKinlay (1985) showed that undersown perennial ryegrass can reduce the density of potato aphids. Akthar and Mahmoud (1996) found that populations of plant parasitic nematodes were significantly suppressed and total yield increased when potato was grown with rocket salad (*Eruca vesicaria*) in alternate rows.

Steiner (1982) states in a review on mixed cropping for low-input agriculture that potato diseases are significantly less prevalent when potatoes are inter-cropped with lupines and beans.
Raymundo and Alcazar (1983) found that potato grown in association with tomato, onion, maize, soybean or beans had significantly less tuber damage from *Phthorimaea operculella* (Zell.) than for potato alone. Autrique and Potts (1987) found that potatoes grown with maize or haricot beans (*Phaseolus vulgaris*) markedly reduced the incidence and rate of bacterial wilt development.

Mixing potatoes and faba beans has shown promising results in terms of reduced incidence of late blight in potatoes and yield increase (Sharaiha et al. 1989). Aphids are the main problem in organic faba bean production and intercropping has been suggested as a strategy for reducing this problem (Patriquin et al. 1988). However, optimal row spacing for faba bean is relatively narrow, so the wider row spacing necessary for intercropping with potatoes might have a negative effect on yield. For autumn sown faba bean (not possible in Denmark) it has been demonstrated that different row spacings (11.9, 23.8 or 47.6 cm) does not affect yield (Pilbeam et al. 1990). This, however, cannot be expected to apply to spring sown faba bean, where approximately 15-20 cm are considered as an optimum (Rao et al. 1984, Kondra 1975). However, recent Canadian studies have shown that row spacings up to 60 cm not always limit yield (Wahab 1999). Faba bean can be grown successfully in ridges. Especially, if several rows of faba bean are sown on each ridge (Salem 1984). Salih (1985) found that faba bean yield increased with number of rows (1, 2 and 3) per ridge with ridges 60 cm apart. Dawelbeit (1988), however, did not find any yield differences between two or three rows of faba bean per ridge spaced 60 or 80 cm apart. Several technical issues have to be solved before mixed cropping of potato and faba bean can be employed in organic farming.

5. 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

Achievements: The project will create a solid basis for evaluating the potential of ridge tillage and mixed cropping in row crops with emphasis on potatoes. We assume that ridge tillage as well as mixed cropping both hold the prospects to improve yield and quality in potatoes. By running the project we will be able to justify our assumptions, contribute to the scientific knowledge about ridge tillage and mixed cropping and hopefully improve organic row crop production.

6. Description of workpackages including methods

Table 1: Workpackage list

Workpackage Number	Work package title	Responsible participant	Budget (DKK1000)	Start	End
WP1	Protecting nitrogen from leaching in ridge tillage systems	JR	1091	1/9 2000	30/6 2004
WP2	Growing row crops in ridge tillage systems with and without catch crops	JR	1938	1/9 2000	30/6 2004
WP3	Growing row crops in ridge tillage systems with and without catch crops with emphasis on stem canker (*R. solani*) in potato	LB	528	1/9 2001	31/12 2003
WP4	Improving crop growth by subsoiling in different tillage systems	JR	242	1/9 2000	30/6 2004
WP5	Mixing potato varieties	LM	757	1/3 2001	31/12 2002
WP6	Mixing potato and faba beans	JPM	444	1/3 2001	30/6 2004

Table 2: Description of workpackages

WP1: Protecting nitrogen from leaching in ridge tillage systems

Workpackage number:	WP1	
Start date or starting event:	September 2000	
Responsible person:	JR	
Contributing persons:	JR	CBH
Person-months:	2	18

Objectives:

1. To optimise ridge tillage for reducing nitrate leaching
2. To evaluate ridge tillage as an alternative to mouldboard ploughing for reducing nitrate leaching in autumn and winter

Description of work:

Task 1. Optimising ridge tillage to reduce nitrate leaching
Different methods for setting up ridges in autumn and growing catch crops in these ridges are investigated in order to reduce nitrate leaching and increase plant available nitrogen in the ridge tillage system as much as possible. Several smaller field experiments are conducted to investigate:

a) the effects of varying the shape, size and orientation of ridges
b) the effects of varying the type and placement of crop residues and animal manure
c) the effects of varying timing of setting up ridges
d) the effects of growing catch crops on ridges
Nitrate leaching is determined by measuring soil inorganic nitrogen in different soil layers at appropriate intervals or simulated and measured indirectly by using Br^- as a tracer. N-mineralisation/immobilisation is determined by the use of ^{15}N pool dilution. In experiments with catch crops the growth, yield and nitrogen uptake of subsequent row crops are determined (see WP2). In other experiments ridges are levelled in spring and the growth and nitrogen uptake of a subsequent broadcast crop (barley, wheat or charlock) is followed by repeated plant sampling to determine plant available nitrogen. All field experiments are conducted at KVL on a loamy soil and some of the experiments are conducted with fewer measurements on sand at Jyndevad. Ridge tillage is compared with traditional mouldboard ploughing. At both KVL and Jyndevad yield and nitrogen content are determined at harvest.

Task 2. Measuring nitrate leaching in lysimeter experiments
To get a more accurate assessment of nitrate leaching lysimeter experiments at KVL are also conducted. These experiments will be planned continuously to verify the most interesting results obtained in the field experiments. In autumn 2000 a factorial experiment with soil tillage (ridge tillage and autumn ploughing) and fertilisation level of a previous maize crop (50, 100, 200 kg N/ha) will be performed to study the interaction of tillage system and residual N on nitrate leaching.

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 (Medio 2003)
2. The effects of shape, size and orientation of ridges has been determined (Ultimo 2003)
3. The effects of type and placement of crop residues and animal manure has been determined (Ultimo 2003)
4. The effects of timing of setting up ridges has been determined (Ultimo 2003)
5. The effects of growing catch crops on ridges has been determined (Ultimo 2003)
6. Final evaluation of ridge tillage as an alternative to mouldboard ploughing for reducing nitrate leaching (Medio 2004)
7. Papers have been written (Medio 2004)

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

Workpackage number:	WP2		
Start date or starting event:	September 2000		
Responsible person:	JR		
Contributing persons:	JR	CBH	JPM
Person-months:	3	20	7

Objectives:

1. To optimise row crop production in ridge tillage systems
2. To investigate the combined effects of soil tillage system and catch crops
3. To investigate the combined effects of soil tillage system and manuring on potato yield and quality.
4. To compare crop yield, energy consumption and economy in organic row crop production using either traditional tillage or different variations of the ridge tillage system
5. To evaluate ridge tillage as an alternative to traditional tillage for improving organic row crop production

Description of work:

Task 1. Optimising crop production in ridge tillage systems
Different methods for growing row crops in a ridge tillage system with and without catch crops are investigated in order to optimise growth conditions and increase yield. Potatoes are grown in traditional spring ridges or in ridges set up in autumn. Maize and sugar beets are grown in traditional seedbeds or in truncated ridges, which are either rebuilt during the growing season or after harvest. Three larger field experiments are conducted to compare different tillage systems with and without catch crops. Experiment 1 is conducted with potato at two soil types (KVL and Jyndevad). The design is factorial with soil tillage and catch crops as factors. Soil tillage includes ridge tillage, autumn ploughing and spring ploughing. Catch crop is biased to soil tillage. Oil radish is chosen in systems based on autumn tillage and under-sown rye grass is chosen in the system based on spring ploughing. The preceding crop to potato is a spring cereal. Tuber yield and quality is determined and assessment of late blight, stem canker and weeds is performed. Experiment 2 and 3 is set up as described above but is conducted with maize and sugar beets at KVL. Crop establishment, yield and nitrogen uptake is determined and assessment of weeds is performed.

Task 2. Investigating the interactions between soil tillage and manuring
To investigate the interaction between soil tillage and manuring Experiment 4 is conducted with potato at the ecological workshop site in Jyndevad. The design is factorial with 1) soil tillage, 2) type of manure and 3) amount of manure as factors. Soil tillage is ridge tillage and autumn ploughing followed by ridges set up in spring. Type of manure is deep litter and liquid manure. Amount of manure equals 80 kg N/ha and 140 kg N/ha. In this experiment crop establishment and yield is determined and assessment of late blight, stem canker and weeds is performed. The effect on tuber quality will be evaluated in cooking tests.

Task 3. Estimating energy consumption and economy of ridge tillage for organic row crop production
Based on estimates and measurements of fuel consumption, working hours, added manure and yield in the experiments above a calculation of the energy consumption and economy of row crop production using either traditional tillage or different variants of the ridge tillage system is performed.

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 (Medio 2003)
2. The performance of tillage systems based on ploughing and ridges with and without catch crops has been determined (Ultimo 2003)
3. The effects of soil tillage and timing/type of animal manure has been determined (Ultimo 2003)
4. The energy consumption and economy of ridge tillage for organic row crop production has been determined (Primo 2004)
5. Final evaluation of ridge tillage for organic row crop production (Medio 2004)
6. Papers have been written (Medio 2004)

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

Workpackage number: WP3
Start date or starting event: July 2001
Responsible person: LB
Contributing persons: LB
Person-months: 5

Objectives:

1. To investigate the effect of catch crops in a ridge tillage system on *R. solani* stem canker in potato caused by either soil-borne inoculum or seed tubers severely infested with black scurf.
2. To evaluate the effect of different soil tillage systems with and without catch crops on potato stem canker

Description of work:

Task 1. Investigating the effect of catch crops on potato stem canker
The effect of catch crops on stem canker in potato will be tested in two following years in Experiment 1 as described in WP2. In field trials either soil-borne inoculum or seed tubers severely infested with black scurf will be used as inoculum source. In the field trial, space is left for testing the effect of organic amendments on soil-borne inoculum incorporated into ridges in the autumn with inoculum coming from seed tubers severely infested with black scurf in the spring.

The following treatments will be incorporated in Experiment 1 described in WP2

1: No inoculum, 0% black scurf on seeds in spring
2: Soil-borne inoculum incorporated in the autumn, 0% black scurf on seeds in spring
3: Seed-borne inoculum, >5% black scurf on seeds in spring.

Each treatment includes 15 plants within each plot. Assessment of stem canker is performed and tuber yield and quality is determined.

Deliverables:

1. Evaluation of ridge tillage with organic soil amendments on *R. solani* stem canker
2. Evaluation of the importance of soil-borne inoculum versus seeds with black scurf in ridge tillage with organic amendments
3. Paper in international journal on catch crops in a ridge tillage system with emphasis on *R. solani* 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 *R. solani* stem canker

Milestones:

1. Infestation of first year field trials is performed (Ultimo 2001)
2. Healthy and diseased seed tubers have been planted in field trials (Primo 2002)
3. Quantitative and qualitative tuber yields from field trial have been determined (Ultimo 2002)
4. Infestation of second year field trials is performed (Ultimo 2002)
5. Healthy and diseased seed tubers have been planted in field trials (Primo 2003)
6. Field experiments finished (Medio 2003)
7. Quantitative and qualitative tuber yields from second year field trial have been determined (Ultimo 2003)
8. Papers have been written (Ultimo 2003)

WP4: Improving crop growth by subsoiling in different tillage systems

Workpackage number:	WP4	
Start date or starting event:	September 2000	
Responsible person:	JR	
Contributing persons:	CBH	JR
Person-months:	4	1

Objectives:

1. To compare the effects of subsoiling on potato yield and quality in different tillage systems

Description of work:

Task 1. Comparing subsoiling for potato production in different tillage systems
A field experiment at KVL is conducted to investigate interactions between soil tillage system and subsoiling in potatoes. The design is factorial with soil tillage and manuring as the two main factors. Soil tillage is either autumn ploughing followed by spring ridges or autumn ridges. Subsoiling treatment is either subsoiling twice during the growing season or no subsoiling. The experiment will be carried out at two levels of animal manure. Tuber yield and quality is determined and assessment of weeds is performed.

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 (Medio 2003)
2. The effects of subsoiling on potato yield and quality in different tillage systems have been determined (Ultimo 2003)
3. Papers have been written (Medio 2004)

WP5: Mixing potato varieties

Workpackage number:	WP5	
Start date or starting event:	March 2001	
Responsible person:	LM	
Contributing persons:	LM	LB
Person-months:	2	3

Objectives:

1. To assess the effect of potato variety mixtures on the epidemic development of late blight

Description of work:

Task 1. Investigating the effect of potato variety mixtures on late blight development
At two locations (the experimental stations Foulum and St. Jyndevad), field trials with organic grown potatoes will be established, and the influence of variety mixtures on late blight development will be studied. The potato varieties are selected as biologically comparable (ex. maturity) but differing with respect to level of partial resistance. One mixture (four-way mixture) and the four varieties in pure stands will be grown in 30x30 m plots in 4 randomised replicates. A method for assessing late blight severity in mixtures will be developed and assessments will be carried out regularly during the growth season. Disease development in the mixtures (as Area Under Disease Progress Curve=AUDPC) will be compared to disease development in varieties in pure stands. The tuber yield and quality of the mixtures and of the varieties in pure stand will be measured.

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 (Medio 2001).
2. First years field trials have been analysed and possible adjustments of design of the field trials can be decided (Ultimo 2001).
3. AUDPC measurements in three years field trials completed (Ultimo 2002).
4. The efficacy of organic grown potato mixtures as a late blight control measure is determined (Ultimo 2002).

WP6: Mixing potato and faba beans

Workpackage number:	WP6
Start date or starting event:	March 2001
Responsible person:	JPM
Contributing persons:	JPM
Person-months:	4

Objectives:

1. To develop a mixed cropping system with potato and faba bean
2. To investigate if mixing potato and faba beans can reduce attack of late blight in potato and reduce colonisation of aphids in faba beans and thereby increase yields

Description of work:

Task 1. Developing potato and faba bean intercropping
Field experiments will be conducted to develop the potato intercropping with faba bean. The potatoes will be fertilised by placing slurry under the seed potatoes. The faba beans will be seeded on relatively small ridges while seeding potatoes. Row combinations 1:1, 2:1 and 2:2 for potato/faba bean will be employed and compared to pure stands. Weeding will be done mechanically by earthing up the ridges. Harvesting of faba beans will take place when the potato haulm is defoliated due to late blight or maturity and after this the potatoes will be lifted. During the growing season the epidemiology of late blight on potatoes and infestation of aphids on faba bean is recorded. Yields of potatoes and faba bean in intercropping and in pure stands are determined and tuber blight on potatoes is assessed.

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 (Ultimo 2003)
2. Influence of intercropping on potato late blight epidemiology has been determined (Ultimo 2003)
3. Influence of intercropping on aphid abundance in faba bean has been determined (Ultimo 2003)
4. Final evaluation of possibilities and perspectives of potato intercropping with faba bean (Medio 2004)
5. Papers have been written (Medio 2004)

7. Implementation and time schedule

Table 4: Timetable

							2000												2001												2002												2003												2004						
	Month	1	2	3	4	5	6	7	8	9	#	#	#	1	2	3	4	5	6	7	8	9	#	#	#	1	2	3	4	5	6	7	8	9	#	#	#	1	2	3	4	5	6	7	8	9	#	#	#	1	2	3	4	5	6	7	8	9	#	#	#
TASKS																																																													
	Co-ordination																																																												
										x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						
	WP 1:																																																												
1										x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						
2											x	x	x	x	x	x							x	x	x	x	x	x							x	x	x	x	x	x							x	x	x	x	x	x									
	WP 2:																																																												
1										x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						
2										x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						
3																																										x	x	x	x	x	x	x	x	x	x									
	WP 3:																																																												
1																					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x												
	WP4																																																												
1										x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						
	WP5																																																												
1																x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x																								
	WP6																																																												
1																x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						

8. Collaborative partners

Royal Veterinary and Agricultural University, Denmark
Erik Steen Jensen
Carsten Petersen
Inge Knudsen
Dan Funck Jensen
Stefan Olsson
Charlotte Thrane
Arne Astrup
Peter Marckmann

Danish Institute of Agricultural Sciences
Kristian Torup-Kristensen
Ilse K. Rasmussen

Danish Potato Foundation (LKF), Vandel
Karl Tolstrup

Swedish University of Agric. Sciences Uppsala
Berndt Gerhardson

University of Kassel, Germany
Maria R. Finckh

Aberdeen University Centre for Organic Agriculture, Scotland, UK
Carlo Leifert

INRA, France
Didier Andrivon

European network for development of an integrated control strategy of potato late blight (EU.NET.ICP)
Arne Hermansen (N)
Björn Andersson (S)
Magnus Sandström (S)
Asco Hannukkala (FIN)

9. Budget

DJF	2000	2001	2002	2003	2004
Salary (scientific)	30	212	256	168	67
Salary (technical)	24	194	235	168	0
Operation	0	219	244	82	10
Overhead	11	125	147	84	15
Total	65	750	882	502	92
KVL					
Salary (scientific)*	60	412	461	372	128
Salary (technical)	48	172	172	160	0
Operation	30	84	78,5	70	10
Overhead	28	134	142	120	28
Total	166	802	854	722	166
Total	356	1666	1658	1062	258

* The salary for co-ordinator Jesper Rasmussen is not included in the budget as he will be paid by KVL

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1.6 Cultivation in ridges and mixed cropping – new approaches to organic row crop production (CARMINA)

Curriculum Vitae for Jesper Rasmussen

Date of birth: 13th of June 1954

Education:

1979	M.Sc. in Agricultural Sciences from the Royal Veterinary and Agricultural
1986	Ph.D. in Plant Husbandry from the Royal Veterinary and Agricultural University

Work experience:

1980 - 1982	Farmer adviser in Ringstedegnens Landboforening, Ringsted
1982 - 1985	PhD-student at the Royal Veterinary and Agricultural University
1985 - 1987	Assistant professor at the Royal Veterinary and Agricultural University, Department of Crop Husbandry
1987 - 1997	Scientist at The Danish Institute of Plant and Soil Science (DIPS), Department of Weed Control and Pesticide Ecology.
1994- 1997	Leader of the section "Physical Weed Control", The Danish Institute of Plant and Soil Science (DIPS), Department of Weed Control and Pesticide Ecology.
1994- 1997	Examinator at the Royal Veterinary and Agricultural University, Department of Crop Husbandry
1995- 1996	Leader of an inter-disciplinary group (4 months per year) that co-ordinates research activities on organic farming at The Danish Institute of Plant and Soil Science (DIPS)
1996-	Associate professor in organic farming at the Royal Veterinary and Agricultural University, with the responsibility of two courses in organic farming.

At The Danish Institute of Plant and Soil Science (DIPS) I established the area of physical weed control. I have been involved in several projects concerning weed biology as well as weed control by physical means. In 1993 I established a European working group in Physical Weed Control within European Weed Research Society (EWRS) in a team-work with Daniel T. Baumann (CH). I have published more than 20 papers in English on physical weed and a much higher number in Danish. At the Royal Veterinary and Agricultural University I am working with several aspect of organic farming within the disciplines of weed science, soil tillage and crop husbandry. I am running a project about Kemink Exact Soil Tillage.

1.6 Cultivation in ridges and mixed cropping – new approaches to organic row crop production (CARMINA)

Curriculum Vitae for Lisa Munk

Date of birth: 25th September 1951

Education:

1977	M.Sc. (cand.agro) in Agricultural Sciences from the Royal Veterinary and Agricultural
1978	University (KVL).
1984	Ph.D in Plant Pathology from The Royal Veterinary and Agricultural University

Employment:

1977 - 1980	Research assistant at Department of Plant Pathology, KVL. Grant from The Danish Agricultural and Veterinary Research Council.
1980 - 1983	Ph.D.-student at Department of Plant Pathology. Scholarship from KVL.
1983 - 1983	Research assistant (4 months) at Department of Plant Pathology, KVL. A grant from The Danish Agricultural and Veterinary Research Council.
1983 - 1983	Assistant professor (substitute) for 4 months at Department of Plant Pathology, KVL.
1984 - 1984	Research assistant (7 months) at Department of Plant Pathology, KVL. A grant from The Danish Agricultural and Veterinary Research Council.
1984 - 1984	Assistant professor (substitute) for 2 months at Department of Plant Pathology, KVL.
1984 - 1985	Assistant professor at Department of Plant Pathology, KVL.
1985 -	Associate professor at Department of Plant Pathology, (now Department of Plant Biology) KVL.
1991 -	Head of Department of Plant Biology.

Field of work

Different aspects of population dynamics and epidemiology in relation to fungal pathogens of cereals and brassicas. The research has included experimental work on control strategies based on race specific resistance (heterogeneous crops), effects of nitrogen on powdery mildew epidemics in cereals and resistance to downy mildew and Alternarias in Brassicas.

Graduate and Postgraduate teaching:

1986 - present: Supervisor for approx. 70 M.Sc.-projects and 50 minor papers written by M.Sc.students.
1987 - present: Supervisor for 8 Ph.D. students of which 6 has completed

Selected publications:

Kølster, P., L. Munk and O. Stølen. 1989. Disease severity and grain yield in barley multilines with resistance to powdery mildew. Crop Science 29: 1459-1463.

Jensen, B. and L. Munk. 1997. Nitrogen induced changes in colony density and spore production of *Erysiphe graminis* f.sp. *hordei* on seedlings of six spring barley cultivars. Plant Pathology 46: 191-202

Hovmøller, M.S., H. Østergård and L. Munk 1997: Modelling virulence dynamics of airborne plant pathogens in relation to selection induced by host resistance. In: The Gene-for-Gene Relationship in Plant-Parasite Interactions, I.R. Crute, E.B. Holub, J.J. Burdon (eds.). CAB International, Wallingford, UK, p. 173-190.

Munk, L. 1998. Variety mixtures: 19 years of experience in Denmark.In: Cost 817, Aims and Progress, Airborne pathgens of cereals (ed. B.M. Cooke). Directorate-General Science, Research and Development, European Commission, p. 19-20.

Jensen, B.D., J. Hockenhull and L. Munk. 1999. Seedling and adult plant resistance to downy mildew (*Peronospora parasitica)* in cauliflower (*Brassica oleracea* convar. *botrytis* var *botrytis*). Plant Pathology 48: 604-612.

1.6 Cultivation in ridges and mixed cropping – new approaches to organic row crop production (CARMINA)

Curriculum Vitae for Lars Bødker

Date of birth: 31th of December 1960

Education:
1988 M.Sc agronomy, The Royal Vet. and Agricultural Univ.
1992 Ph.D. degree in Plant pathology

Employment:
1989 Scientist at Danish Institute of Plant and Soil Science
1991 Visiting scientist at University of East Anglia, England
1994 Senior Scientist at Danish Institute of Plant and Soil Science

Other activities

External examiner at KVL, and University of Copenhagen

Referee on Plant Pathology, Phytopathologia mediterranea and Acta Agriculturæ Scandinavica.

Main research projects:

The main research projects have mainly been within root diseases of vegetables on the disease surveys in vegetables and potatoes in Denmark. The research has mainly focused on mycological studies, resistance and characterisation of pathogens using molecular techniques (PCR, RFLP, PFGE, VCG-test) in both organic and conventional growing systems. In the last three years the work has primarily been focused on integrated disease control of root rot of peas and cavity spot of carrots using organic amendments and improvement of control strategies for late blight in potato.

Research interests:

My main research interest is the study of natural regulation mechanisms in relation to the use of different types of organic amendments. Research of this kind has been performed have been performed in peas, carrot and potato with focus on autumn green manure crops. The interaction between mycorrhizal fungi and root pathogens is of major interest. However, it is very important that the results will be applicable to practical farming systems.

Some recent publications

Bødker, L. & K. Thorup-Kristensen 1999. Effect of green manure crops on root rot and arbuscular mycorrhizal fungi in pea roots. 337-344. Olesen, J.E., Eltun, R., Gooding, M.J., Jensen, E.S. & Köpke, U. (Eds) Designing and testing crop rotations for organic farming. DARCOF Report no. 1.

Larsen, J., Mansfeld-Giese, K. & L. Bødker 1999. Quantification of *Aphanomyces euteiches* in pea roots by the use of fatty acid signatures (Accepted for Mycological Research).

Bødker, L., Kjøller, R and Rosendahl, V. 1998. Effect of phosphorus and the arbuscular mycorrhizal fungus Glomus intraradices on disease severity of root rot of peas (Pisum sativum) caused by *Aphanomyces euteiches*. Mycorrhiza 8, 169-174.

Persson, L., Bødker, L. and Larsson-Wikström, M. 1997. Prevalence and pathogenicity of root and foot rot of peas in Southern Scandinavia. Plant Disease 81 (171-174).

1.6 Cultivation in ridges and mixed cropping – new approaches to organic row crop production (CARMINA)

<u>Curriculum Vitae for Jens Peter Mølgaard</u>

Date of birth: 16th of May 1961.

Education:

1991	Ph.D. agr., The Royal Veterinary and Agricultural University.
1988	M.Sc. hort., The Royal Veterinary and Agricultural University.

Employments:

1992-	Scientist, Department of Forage Crops and Potatoes, Danish Institute of Plant and Soil Science, (now: Department of Crop Physiology and Soil Science, Danish Institute of Agricultural Sciences), Research Centre Foulum.
1988-1991	Research scholarship, Department of Agricultural Sciences, The Royal Veterinary and Agricultural University (Ph.D.).
1980-1981	Labourer in agriculture and horticulture.

Courses:

1997	Project management, Sector Research Institutes, The Ministry of Food, Agriculture and Fisheries.
1997	Project planning and control, Sector Research Institutes, The Ministry of Food, Agriculture and Fisheries.
1996	Systems research in ecological agriculture, Second Nordic postgraduate course in ecological agriculture, Norway.
1994	Ecology and Modelling of Potato Crops under conditions Limiting Growth. Summerschool: Second International Potato Modelling Conference, Wageningen.

Occupation:

My prime area of research is the influence of agronomy and storage on the quality of potatoes. Manager of projects on organic potato production concerning tuber quality and potato diseases. Furthermore, I am engaged in a review project on organic products and their influence on human health. My Ph.D. research was on plant breeding and biotechnology.

Publications

Mølgaard, J.P. (1997): Organic Potato Production - Quality aspects. A Danish Research Project. Joint Agronomy-Utilization Conference of the European Association for Potato Research (EAPR), Abstract of papers, 21-22.

Mølgaard, J.P. (1998): Kartofler på en ny måde – nye anbefalinger til gødskning og ukrudtsbekæmpelse i økologiske kartofler. Økologisk Jordbrug 18(169): 9.

Mølgaard, J.P. (1998): Økologisk kartoffeldyrkning – gødskning og kvalitet. Kartoffelproduktion 1998/5: 8-10.

Mølgaard, J.P. (1999): Økologisk kartoffeldyrkning i Danmark – status og forsøg. Grønn forskning (Planteforsk, Norsk institutt for planteforsking) 2/99: 61-65.

Mølgaard, J.P., Mikkelsen, G. & Holm, S. (1999): Effects of different types of animal manure on the quality of organically grown potatoes. 14th triennenial conference of the European Association for Potato Research (EAPR), Sorrento, Italy, Abstracts, 341-342.

1.6 Cultivation in ridges and mixed cropping – new approaches to organic row crop production (CARMINA)

Curriculum Vitae for Christian Bugge Henriksen

Date of birth: 13th of November 1968

Education: M.Sc agronomy, The Royal Vet. and Agricultural Univ.

Employment:

1995 - 1998 Research assistant, Dept. Crop Science, The Royal Vet. and Agricultural Univ.

1998 - Ph.D. student, Dept. Crop Science, The Royal Vet. and Agricultural Univ.

Occupation:

Since 1998 I have been working on a Ph.D. project titled "Soil tillage in organic farming systems". In this project I am investigating the different components of the Kemink exact soil tillage system, which is based on controlled traffic, subsoiling and autumn ridges. I have been focussing on crop growth and nitrogen dynamics. As a part of the project I have been conducting several field experiments to evaluate the effects of ridges and subsoiling on soil inorganic nitrogen and growth, yield and nitrogen uptake of subsequent crops.

Publications:

Henriksen, C.B., Rasmussen, J. and Søgaard, C. (1999): Jordkamme kan erstatte ploven. Økologisk Jordbrug 19:12

Søgaard, C., Henriksen C.B. (1999). Hvordan virker Kemink metoden i praxis? Praktisk Økologi 5 (19).