Danish Research Centre for Organic Farming

Annual Status Report 2001 and Application for Continuation in 2002

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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.5 Grain legumes and cereals – new production methods for increased protein supply in organic farming systems. Acronym: GENESIS

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7. Start of project: September 2000
End of project: December 2003

8. Annual report/Application for continuation in 2001

A. Objectives and expected achievements (from application)

1. Grain legumes for mono- and intercropping in organic farming systems
The objectives are:

- to determine grain and straw yield, nitrogen fixation and the quality of seeds of pea, faba bean and narrow-leaf lupine types grown in organic farming systems on two soil types during three years.
- to determine strategies for rotation and choice of grain legume crops.
- to evaluate available varieties and breeding lines potential for mono- and intercropping of peas, faba beans, lupines spring barley, wheat and triticale.
- to evaluate ideotypes of narrow-leaf lupine with different growth rhythm, total height and branching structure for their qualities for intercropping and weed suppression ability.

Achievements: The research will improve the basis for species and variety choice of grain legumes in monocropping and determine optimum combinations of these in intercropping systems with cereals. The potential and stability of the legume components and the system in relation to soil type/climatic variation will be established. The research will also lead to a better understanding of how variation in grain legume phenology can be exploited in organic farming.

2. Performance of grain legumes and cereals at low K and P levels
The objectives are to:

- determine the effect of low K-status on the production of protein in grain legume and cereal crops on a coarse sandy soil,
- improve the basis for decisions about K-fertilisation to these crops,
- determine the relative tolerance of the different grain legumes (and cereals) to low plant available soil P,
- assess the P uptake, yield and seed quality at low P levels of the different grain legume crops.

Achievements: The work will improve the basis for a high protein production on coarse sandy soils with low content of exchangeable K through increased knowledge about the performance of different cereal and grain legume crops and their pre-crop effect. The work will indicate to which extend differences exist between grain legume species and varieties in recovering and utilise P from soils low in available P.

3. Intercropping of grain legumes and cereals: resource use and weed management
The objectives are to:

- determine the effect of intercropping of pea, faba bean or narrow-leaf lupine types with cereals on the yield, nitrogen use, yield stability (3 years), residual soil N and the quality of grain legume and cereal seeds as compared to monocrops on two soil types, and
- determine the competition and use of multiple resources in intercrop/weed and monocrop/weed communities of pea barley intercrops as influenced by intercropping design and the plant population density, in order to evaluate the potential for weed management by intercropping and/or plant density in grain legume monocrops.

Achievements: The research will improve the basis for evaluating the suitability of intercropping (multi-functional plant production) for organic cropping systems. More specific, knowledge will be obtained about the potential for intercropping of grain legumes and cereals as a method to increase the protein production in organic farming, without comprising the yield stability and without the risk of increased leaching of N in autumn/winter, which may be associated with the growing of grain legumes as monocrops. The project will contribute to building of knowledge regarding the mechanisms involved and the practical use of intercropping and grain legume plant density as means to control weeds.

4. Plant health in grain legume and cereal crops
The objectives are to:

- determine how intercropping systems of grain legumes and cereals affects establishment and development of relevant diseases, and
- achieve a better understanding of how changed quality and physiology of plants, due to different availability of nutrients (N, K and Si) in low K soils or intercropping, affects disease resistance mechanisms

Achievements: The project will help to make guidelines for proper nutrient management and intercropping in relation to disease control and help to facilitate breeding for cultivars better suited to organic conditions. This will be achieved by examining disease problems related to low K soils, determining the effects of intercropping of cereals and legumes on disease problems, and by characterising and quantifying these effects on disease resistance mechanisms.

5. Quality aspects
The objective is to perform a thorough chemical and nutritional characterisation of selected varieties of peas, faba beans and narrow-leaf lupines grown as monocrops or intercropped with cereals as influenced by soil type and nutritional status of the soil on:

- Chemical composition - protein, fat, carbohydrates (alpha-galactosides, non-starch polysaccharides) and amino acids,
- Digestibility of nutrient fractions based on in vitro analyses, and
- Secondary factors influencing the nutritive quality based on specific analyses of ANFs and a biological model using a standardised rat-bioassay

Achievements: This project will increase the knowledge on the effect on the nutritional quality, including composition of available nutrients and anti-nutrients, of crops grown under organic farming conditions.

B. Project summary (from application)

There is an urgent requirement for an increased local/on-farm production of protein and cereal crops in Danish organic farming system to meet the increasing demand for the feeding of monogastric animals (pigs and poultry). Grain legumes, such as pea, faba bean and lupins, and cereals can complement each other in animal feeds and these grain legumes are the best suited species for the Danish climatic conditions. Besides being valuable protein and energy sources in animal feeds (and in human diets low in meat), grain legumes benefit the farming system via biological N_2 fixation and by their effect as break-crop for cereal diseases in rotations. However, grain legumes have the reputation of high yield variability, due to low tolerance to water stress and lodging for some species, late maturity for others and variability of the seed quality.

The principal aim of the project is to evaluate the potential for increased protein production for animal feed via the growing of grain legumes in organic cropping systems. The project will identify potential obstacles to the production via studies on the effect of soil type/climate, potassium and phosphorus availability, plant diseases and weeds on grain legume and cereal yields. New methods for protein production to be evaluated are: intercropping of grain legumes and cereals and the role of plant density in relation to weed management in grain legumes. In the project grain legumes species and genotypes will be evaluated in relation to their suitability for organic cropping systems, more specifically for intercropping and weed management. Finally, N_2 fixation, crop N balances, N availability in the autumn and in succeeding crops and the quality of grain legumes seeds in relation to feeding of monogastric animals will be determined.

The project also aims to contributing basic knowledge regarding fundamental processes in organic farming systems. This includes studies on the relationship between grain legume phenology and competitive ability of the crops towards weeds and the suitability for intercropping, the variability in crop tolerance to low nutrient status (P and K) of grain legumes, multiple resource use by intercrop/weed communities, evaluation of possible mechanisms of weed control by an intercrop, the possible role of competition as a mean to control the quality of the plant products, the establishment and development of diseases in intercrops, the role of plant nutrient status in plant health and the nutritional effect of grain legumes and cereals produced in organic farming systems.

Table 1: Work package list (from application)

No.	Work package title	Participants*	Budget (1.000 DKr)	Start	End	Deliverable No:
1	Evaluation of potential grain legumes for mono-intercropping with cereals	BJ, JLC, ESJ, NN	1400	April 2000	Dec. 2003	1-4
2	Performance of grain legumes and cereals at low K and P levels	MA, BJ,	940	April 2000	Dec. 2003	5-8
3	Intercropping of grain legumes and cereals: resource use and weed management	ESJ, NN, BJ, CA, VL	2160	Feb. 2001	Dec. 2003	9-13
4	Plant health in relation to intercropping and nutrient uptake	ML, MM	1400	Feb. 2001	Dec. 2001	14-16
5	Quality of grain legumes and cereals and isotope analysis	KEBK, SB, PA	670	Sept. 2001	Dec. 2003	17-21

* Responsible participants are underlined

C. Progress

C.1 Annual description (resume) of main results and conclusions

WP1: Grain legumes for mono- and intercropping in organic farming systems

Task 1: Screening potential genotypes for mono- and intercropping

The two years field experiment under this task 1 was finished this year. The experiment was carried out at the KVL experimental station outside Copenhagen on a sandy loam. In 28 pea, 12 spring beans, 8 lupin, 11 spring barley, 10 spring triticale and 8 spring wheat were tested in mono and inter cropping, at respectively normal sowing density and at 50% of normal density in the mixed plots. The grain legumes were tested in mixtures with one standard spring barley variety Otira and the cereals were tested in mixtures with one standard pea variety Agadir. A randomised block design with 2 replicates were used where one plot of each of the monocrops and their mixture were grouped together. In total it made up 462 plot each year. Plant development including the time of key development stages and plant heights in mono crop and in the mixed plot were followed during the growing season.

All plots were combined harvested and representative genotypes within each species were hand harvested for determination of total biomass and harvest index the different combinations of species and varieties. From results in year 2000 it was found that short stem peas and early ripening narrow leafed lupins with restricted branched were the best option for intercropping with spring barley and - wheat, with respect to synchronized development and stand ability. Traditional branched lupins and spring beans outgrew and ripened much later than the inter-cropped cereals. Weed infestations decreased slightly in the mixtures of grain legumes with barley compared to the barley monocrop and several times compared to the legume monocrops

Task 2. Production, yield variability, nitrogen fixation and quality of grain legumes on two soil types.
The experiment was carried out at the locations Højbakke and Jyndevad (a similar experiemtn will be carried out in 2002 and 2003). One genotype of spring bean, one of lupin, a semi-leafless and a normal leafed pea variety and a standard feed barley and a high lysine variety was selected for the experiment based on the results in WP1 task 1. These varieties were grown in monocrops at standard sowing rate, and the barley varieties intercropped with the different legume varieties at densities reduced to 50% of normal for respective species (see WP3). In total it made up 16 combinations in 4 replicates at each location. After emergence of the cereals and legumes ryegrass was undersown to catch nitrogen during autumn and winter. The development, including the time of key development stages and plant heights in monoculture and in the mixed plot was followed during the growing season. At ripening one m^2 were hand harvested in all plots for determination of total biomass and harvest index. The remaining part of the plots were combined harvested for later quality analysis in WP5 and for measurement of nitrogen content, grain size and N fixation by the natural abundance method.

Task 3. Ideotypes for intercropping
Narrow leafed lupin is used as a model crop. The first year experiment was performed at Højbakke Experimental station. 12 genotype varying earliness of stem elongation and branching structure were grown at 100 plants per m^2 in mixture with one barley variety sown at 50 plants m^2. The height development was followed during the growing season and at ripening samples was taken for later determination of plant structure of the lupines and the effect of the different lupin growth forms on the barley and the natural occurring weeds.

WP2: Performance of grain legumes and cereals at low K and P levels
Task 1. Determination of the effect of low K-status on the production of protein in cereal and grain legume crops on a coarse sandy soil (Table 1).

After an initial year in 2000, where the area at Jyndevad Experimental station was covered with grass-clover for cutting in order to reduce the soil K-status, the field experiment was initiated in spring 2001 according to the plan. Four different crops, spring barley, pea/barley, field bean and lupine, representing different levels of protein content was well established. Blind harrowing and weed harrowing were performed until sowing of the catch crops at growth stage BBCH 31 (barley). The fields were irrigated with about 30 mm four times during the growing season. Plant and soil samples were collected from the plots 6 times during the growing season. Visual symptoms on K deficiency were lacking despite a low level of exchangeable K of about 2.4 mg 100 g $soil^{-1}$. However, late in the growth season the field beans in the +K treatments was higher than in the –K treatments and the flower buds of the peas became necrotic in the –K treatments. In the middle of the seed filling the lupins were severely attacked by botrytis. Analysis of K uptake in the crops and the corresponding changes in the soil K fractions are in progress. Crop yields will be available in November.

Table 1. Treatments in task1

Treatments	Cover crop	K (kg ha^{-1})	Replicates
1	Spring barley	0	4
2	Pea/barley	0	4
3	Lupine	0	4
4	Field bean	0	4
5	Spring barley	80	4
6	Pea/barley	80	4
7	Lupine	80	4
8	Field bean	80	4

Task 3. Quantification of the P uptake of different grain legume species, cereals and their intercropped mixtures to estimate their performance at low soil P levels.

Based of the evaluation of genotypes in WP1 in year 2000 one genotype of barley, peas, field bean and lupine were selected for the P experiment. The experiment was established at Højbakke experimental unit concerning long time effect of increasing application of N, P and K in cattle slurry and commercial fertiliser on soil quality, fertility and plant nutrition. The permanent design includes seven combinations of fertilizer level repeated two times. The total length of the experimental area is nearly 300 m. At each of the 14 main plot the seven combinations consisting of the four monocrop and the three mixture combinations of barley intercropped with pea, field bean and lupin, respectively. The experiment was sown at the beginning of May. Despite the installation of three bird scare alarms the trial was severely damaged by birds and hares in a systematic way leaving the plots near the alarms relatively undamaged. The experiment were abandoned as the results would have been biased due to the systematic damage in some treatments and the preference of the birds of legumes over cereals and spring bean seeds over lupins and peas.

WP3: Intercropping of grain legumes and cereals: resource use and weed management.
Task 1: Intercropping of grain legumes and cereals on two soil types during three years.

The objectives of task 1 activities are to determine the effect of intercropping of pea, faba-bean or narrow-leaf lupine types with cereals on the yield, nitrogen use, yield stability (3 years), residual soil N and the quality of grain legume and cereal seeds as compared to sole crops on two soil types.

Two identical field trials were established at Højbakkegård and Jyndevand Research Station:

Experimental set-up

Species	Barley, pea, faba-bean and narrow-leaf lupin
Cultivars	Pea – Bohatyr and Agadir (normal leafs versus semi-leafless with tendrils, respectively) Faba-bean – Colombo (a cultivars suitable for the Danish climate, maturing reasonable early (also used in WP2)). Lupin – Prima (a well-known and promising cultivar maturing reasonably early)
Design	All crops were grown as sole crops and barley-grain legume intercrops employing replacement design. Barley and the grain legume grains were mixed and sown in rows 15 cm apart in 0.5:0.5 ratios. The rationale of this design is that the interactions between intercrop components are not confounded by alterations in the relative total plant density in the intercrop compared to sole crops. The crops were undersown with ryegrass to capture inorganic residual soil N.
Management	From knowledge about previous crops and fertilization it was decided not to apply any nutrients to the field except in the sole crops of barley where we included a 0 and 50 kg urea-N ha^{-1} treatment. The site was managed with no use of herbicides or mechanical weeding. Scarecrows were used to avoid birds.
Sampling	The day before sowing, the soil was sampled in successive soil depths, i.e. 0-25, 25-50, 50-75, 75-100 and 100-125 cm. Harvest was conducted at maturity by cutting the plants above the soil surface ($1m^2$). The plant biomass was separated in crop and weed fractions, the latter including non-recognisable dead tissue. Grain dry matter yield is determined separately for both pea and barley after threshing. After hand-harvesting, each plot were combine harvested and grains were sampled and kept for future quality aspects. All straw left on the soil were removed the same day to secure good growth conditions for the undersown ryegrass.
Analysis	During growth the trial was characterised for plant development, including height during growth, time of flowering and ripening and other special characteristics observed comparing sole – and intercrops. Aboveground dry matter and nitrogen yields (straw and grain), nitrogen use and fixation (natural abundance), residual soil N and the quality of grain legume and cereal seeds as compared to sole and intercrops on two soil types are included in this field experimentation

The plans for the experiments were accurately followed during the season but due to the wet and rather cold spring sowing were delayed (1-2 month later than normal) resulting in rather poor crop growth at Jyndevad, whereas the trial at Højbakkegård performed reasonable well. However, all samples are still being processed and analysed in the lab and at this stage we have no results to present.

Task 2: Use of multiple resources by intercrop/weed and monocrop/weed communities
The objective of the first task 2 activities were to determine the competition and use of multiple resources in intercrop/weed and sole crop/weed communities of pea and barley intercrops in order to identify specific growth factors regulating interspecific competition using semi-controlled growth conditions.

In order to be able to monitor multiple resource use a semi-field pot (25 cm w x 40 cm h) experiment was conducted using aviary facilities at Højbakkegård. A sandy loam soil from Højbakkegård was used (20 kg dry soil pot^{-1}) when implementing six crop treatments using *Sinapis alba* as a model weed.

Crops	Plants pot^{-1}	Weeds pot^{-1}
Sole crops		
Barley (Otira)	30	5
Pea (Bohatyr)	8	5
½ Barley	15	5
½ Pea	4	5
Intercrops		
½ Barley+ ½ Pea	15+4	5
$^1/_3$ Barley + $^1/_3$ Pea + $^1/_3$ Brassica napus	10+3+3	5

In the experimental set-up a ± sulphur (S) treatment was included incorporating gypsum. Three harvests were carried out during the experimental period by cutting the plants above the soil surface. Firstly around the tillering/pre-flowering stage, secondly at the end of the elongation/post flowering growth stage and finally at maturity. At each harvest the plant biomass was separated into the different crop species including determining grain dry matter yield after threshing the final harvested biomass. Together with each harvest soil sampling were conducted to measure soil mineral N and S.

Soil texture and nutrient characteristics during growth together with aboveground dry matter, sulphur and nitrogen accumulation (straw and grain) is used to distinguish between specific factors influencing the interspecific competition in the crop community using simple equations like:

$$\text{Dry weight/unit area} = \frac{\textit{capture}\ \frac{\text{unit mass of X uptake}}{\text{unit area}}}{} * \frac{\textit{capture efficiency}\ \frac{\text{dry weight}}{\text{unit mass of X uptake}}}{}$$

One of the aims of this experiment is to define specific growth factors regulating the proportions of components in cereal-grain legume intercrops.

The experiments were conducted successfully without any major remarks. However, the drip-watering set-up may have caused short periodic water limitations during especially the elongation growth stage around mid June. All samples are still being processed and analysed in the lab and at this stage we have no results to present.

Task 3: Effects of intercrop design and plant density on weed growth
The objective of the task 3 field trial was to determine the competition and use of growth resources in intercrop/weed and monocrop/weed communities of pea and barley intercrops as influenced by plant population density in order to evaluate the potential for managing weeds but also grain quality by intercropping and /or plant density in grain legume sole crops.

A pea (Bohatyr) and barley (Otira) intercrop field-trial were conducted using *Brassica napus* as a model weed in the light of the design outlined in the table below:

Density	Plants m^{-2}			
	Barley (B) sole crop	Intercrop 2/3B:1/3P	Intercrop 1/3B:2/3P	Pea (P) sole crop
1	150	100	50	
		15	30	45
2	300	200	100	
		30	60	90
3	600	400	200	
		60	120	180

The experimental plots (1.5 x 8 m) were laid out in a complete two-factorial randomised design with a high and a low weed pressure as the main factor and barley and pea and the respective intercrops as treatments with four replicates.

Management, sampling and analysis was identical to the task 1 field experiment except that we included three harvests in this trial conducted almost at the same time as in the task 2 pot-experiment. Another difference was that we did not include a fertilization treatment in the barley sole crops. Light penetration measurements were also carried out every second week from the early elongation growth stages until grain filling to get a dynamic measure of canopy structure and growth conditions for the weeds.

Again, we conclude that in general we are satisfied with the field experiment except that the Bohatyr pea cultivar in the higher densities were causing considerably lodging in the sole crops as well as in some of the intercrops. Bohatyr was chosen because normal leafed cultivars have a good competitive ability towards weeds but looking at the task 1 field trial we concluded that Agadir would have been a more appropriate choice. About two weeks before sowing, we conducted a false seedbed preparation to pre-germinate the weeds before the actual seedbed preparation were conducted just before sowing. This strategy was very efficient this year giving the Agadir cultivar a lead compared to weeds. However, studies performed in the FØJO I program indicated that semi leafless pea cultivars were not appropriate in high weed pressure systems, and that was the background for choosing Bohatyr.

Samples are being processed and analysed in the laboratory.

WP4: Plant health in grain legume and cereal crops
Task 4. Results on effect of barley-Legume intercrop on disease frequency

Barley
In the Højbakkegård field trial initial signs of disease were observed at flag leaf emergence stage of barley development. The first disease (and most prevalent) was net blotch (*Pyrenophora teres*). Later brown rust and powdery mildew were observed. 'Otira' plants were scored for levels of these diseases between flag leaf emergence and heading.

Treatments: Otira (barley); Otira + Prima (lupin); Otira + Columbo (faba bean); Otira + Bohatyr (pea); Otira + Agadir (pea); Otira + 50 kg N as urea.
A reduction in net blotch was observed in all intercrop treatments. This reduction was statistically significant between Otira and Otira + Bohartyr. These results were confirmed in Højbakkegård 2 weeks later. In Jyndevad the same trends were seen, though there were no significant differences between the treatments.
Brown rust (*Puccinia recondita*) was the next most important disease seen on barley. Powdery mildew (*Blumeria graminis* f. sp. *hordei*) was also observed but at very low levels. Again for both these diseases, in any intercrop treatment there was a lower disease level compared to the barley monocrop, however this reduction in disease was not statistically significant.
For all the diseases observed the presence of added N increased level of disease.

Pea
Only Ascochyta blight was observed on pea in Højbakkegård. Its frequency was very low. When either pea variety ('Bohartyr' or 'Agadir') was intercropped with barley ('Otira' or 'Lysiba'), the level of Ascochyta was reduced and this was significant in the case of Bohatyr V Bohartyr + Otira.

Conclusions: 1) The barley-legume intercrop reduced disease levels on both crops compared to the monocrop. 2) The presence of added N increased disease frequency.

WP5: Quality aspects and isotopic analysis
Samples from WP 1, WP 2 and WP 3 are dried and stored for quality analyses. Samples from intercropping have been divided into their constituents.

Isotopic analyses have not yet been decided.

C.2 Fulfilment of tasks and deadlines in individual work packages

(To be completed for each work package)

WP 1 Evaluation of potential of grain legumes for mono- and intercropping with cereals	**Time schedule according to application**	**Deviations, if any***
Task		
1. Screening of potential genotypes	2000-2001	
2. Production, yield variability, nitrogen fixation and quality of grain legumes on two soil types	2001-2003	
3. Ideotypes for intercropping	2001-2002	
Deliverables		
1. Recommendations for choice of species and varieties of peas, spring beans lupines and spring barley, wheat and triticale for the mono- and intercropping experiments in the other work packages.	2001	
2 Genotypic characteristic for good intercropping and weed suppressing ability.	2003	
3. Paper on yield variability and N_2 fixation in grain legumes on two soil types	2003	
4. Paper on grain legume genotypes for intercropping and weed suppression	2002	
Milestones		
1. Background for selecting genotypes for the experiments in work package 2, 3 and 4.	2001	
2. Recommendations for species and varieties for inter- and mono-cropping .	2003	
3. Recommendations for ideo-types of narrow-leaf lupin for intercropping or weed management.	2003	
WP2 Performance of grain legumes and cereals at low and low P and K levels	**Time schedule according to application**	**Deviations, if any***
Task		
1.Determination of the effect of low K-status on the production of protein in cereal and grain legume crops on a coarse sandy soil.	2001-2003	
3. Comparison the crop performance and P uptake at low levels of P	2001-2003	
Deliverables		
1. Paper on the effect of low K-status on protein production on a coarse sandy soil submitted to international refereed journal.	2003	
2. Paper on the pre crop effect of different grain legumes as affected by K-supply and catch crop type on a coarse sandy soil.	2003	
3. Papers in national agronomic magazines for information about the results.	2003	
4. Paper on P uptake of grain legumes and cereals at low P status soil and their growth performance	2003	
Milestones		
1.The effect of low K-status and K-fertilisation on protein production in different cereal and grain legume crops on coarse sandy soil has been clarified.	2003	
2. Field experiments finished.	2003, aug	
3. The pre crop effect of different cereal and grain legume crops on coarse sandy soil has been clarified.	2003	
4. Characterisation of P uptake capacity of grain legumes and their growth performance at low P status soil	2003	
5. Recommendation for species/genotype choice at low P status soil	2003	

WP3 Intercropping of grain legumes and cereals	**Time schedule according to application**	**Deviations, if any***
Task		
1 Intercropping of grain legumes and cereals on two soil types during three years.	2001-2003	
2 Use of multiple resources by intercrop/weed and monocrop/weed communities	2001-2003	
3 Effects of intercrop design and plant density on weed growth	2001-2003	
Deliverables		
9 Paper on the effects of intercropping grain legumes and cereals at different soil types on various parameters	2003	
10 Paper on multiple resource use by inter- and monocrop of pea and barley	2003	
11 Paper on the competition for multiple resources between intercrops and weeds	2003	
12 Paper on the effect of intercrop design and plant density on the competition with weeds	2003	
13 Guidelines for intercropping grain legumes and cereals for multiple functions in organic cropping systems	2003	
Milestones		
1 Results from field experiments year 1	ultimo 2001	Not finalized before end of spring 2002
2 Results from field experiments year 2		
3 Results from field experiments year 3		
WP4 Disease resistance in relation to intercropping and nutrient uptake	**Time schedule according to application**	**Deviations, if any***
Task		
1 Evaluate effects of growing barley and pea as intercrop on diseases in the field. The following model system will be used: barley attacked by barley powdery mildew (*Blumeria graminis* f.sp. *hordei*) and pea attacked by *Mycosphaerella pinodes*, one of the three phytopathogenic fungi causing *Ascochyta* blight on pea.	01/2001-08/2002	
2 Characterise possible influence of intercropping on disease resistance mechanisms in individual host plants (barley / *B. graminis* and pea / *M. pinodes*) due to changes in nutritional balance/status in the plants.	05/2002-05/2003	
3 Evaluate possible disease problems related to nutrient uptake on sandy soils low in K and characterise possible influence on disease resistance mechanisms in individual host plants (barley / *B. graminis* and pea / *M. pinodes*).	04/2001-07/2003	
4 Monitoring diseases in field plots described in WP2 and WP3.	04/2001-07/2003	
Deliverables		
1 D14.Paper about intercropping and disease resistance	2002	
2 D15.Paper about influence of nutrient uptake on disease resistance	2003	
3 D16. Recommendations of plant characteristics which should be taken into consideration when choosing cultivar or breeding material	2003	

Milestones		
1 Paper about intercropping and disease resistance (December 2002)	2002	
2 Paper about influence of nutrient uptake on disease resistance (May 2003)	2003	
WP5 Quality of grain legumes and cereals and isotopic analysis	**Time schedule according to application**	**Deviations, if any***
Task		
1 Determination of the effect of cultivation system on nutritional quality of grain legumes	2002-2003	
2 Determination of impact of type of soil and K status of soil on nutritional quality of grain legumes	2002-2003	
3. Indentification of possible antinutritional factors in grain legumes	2002-2003	
4. Quality of wheat for bread	2003	
5. Staple isotopes	2002-2003	
Deliverables		
Report on the variation in total nitrogen from the screening study	Dec 2003	
Paper on the effect of cultivation system on the nutritional quality of grain legumes	Dec 2003	
Paper on the impact of type of soil and its K status of soil on the nutritional quality of grain legumes	Dec 2003	
Identification of possible antinutritional factors in peas and faba beans	Dec 2003	
Stable isotope ratios determined for WP1, WP2, WP3	Jan 2002 Jan 2003 Dec 2003	
Milestones		
Evaluation of variation in total nitrogen from the screening study	2002	
Evaluation of impact of cultivation system on the nutritional quality of grain legumes	2003	
Evaluation of impact of type of soil and its K-status on the nutritional quality of grain legumes	2003	
Identification of possible antinutritional factors in grain legumes grown under organic farming conditions	2003	
Evaluation of baking quality of wheat	2003	
Stable isotope ratios determined for WP1, WP2, and WP3	2002, 2003	

** Deviations are to be further discussed at C3*

C.3 Discussion on the progress, incl. deviations and achievements in the project as a whole and in the individual work packages.

The project is in good progress. The whole project group met in a whole day seminar in June and had discussions on links and collaboration in project.

WP1: No deviations from plans
WP2: There are no deviations from the work plan.
The phosphor experiments has been abandoned this year due to severe bird damage.
WP3: No major deviations from plans
WP4: We are following progress as planned (c.f. C.2) and are within the time schedule
WP5: No deviations from plans

D. Description of plans and future work in the project as a whole and in the work package (Including plans for publication and communication)

WP1: The experiments under task 2 and 3 will be repeated next year. It is expected that the work will progress as scheduled.

WP2:
A barley crop will be sown in spring 2002 in order to test the precrop effects of the four tested crops. The precrop effects of barley and lupines are tested with and without use of a catch crop in collaboration with the DARCOF project "Development of organic vegetable cultivation methods, and the use of catch crops to improve the production and protect the environment", WP7. The type of analyses on quality parameters of the harvested grain and seed will be decided later in the autumn. The activities will be repeated two times 2001/2002 and 2002/2003. The plans for publications are presented under C2, deliverables.

Due to the disaster of the P level experiment in year 2001, a neighbour area is reserved for a similar experiment in year 2002. This area is located inside the experimental unit concerning long time effect of increasing application of N, P and K in cattle slurry and commercial fertiliser on soil quality, fertility and plant nutrition.

WP3:
In WP3 the described task-1 experiment will be continued the coming two years. The only change from the present 2001 trial might be sowing a catch crop like Raphanus sativus or Sinapis alba in stead of undersown ryegrass to secure a better soil inorganic N uptake from deeper soil layers. In order to determine the degree of isotopic discrimination (B-Value) between the two stable N isotopes , ^{14}N and ^{15}N, which occurs during N_2 fixation by field pea, faba-bean and lupin a pot experiment will be conducted in the greenhouse during autumn/winter 2001-2002.

Other activities planned in 2002 under task 2 and 3 will not be finalized before some of this years results are evaluated. However, the framework of two field trials is decided.

1. Different intercrop designs (additive, replacement) using different crop densities and grain legumes species together with barley including to levels of weed competition to elucidate the effect of intercropping design on yield and weed suppression according to grain legumes species. The experimental design will be similar to the set-up described in this year's task-3 experiment.
2. In collaboration with WP1 we will conduct another field trial placed beside the trial described above focusing on a multi species/cultivar intercrop approach. The aim is to determine whether a higher biodiversity in the cropping system increase the utilization of multiple resources (task-2) by filling out a higher number of ecological niches due to temporal and spatial differences between intercrop component species and cultivars. When the threshing of aboveground biomass from the WP1 task-1 trials for this year is finalised we will screen for the best cultivars of spring barley, wheat and triticale as our cereal component and pea, faba-bean and lupin as our legume component in the intercrop. The idea is to include 3 cultivars per species screened for growth differences but with similar maturity dates. We will use an additive intercrop design to induce a high degree of interspecific competition. All species and cultivars will be grown as sole crops whereas the cereal-grain legume intercrops will include combinations of species without differentiating between each species cultivars.

WP4:
We are currently following our original plans (c.f. C.2).

WP5:
Analyses have not started yet. However, it has been decided that initially, the samples from WP 2 and WP 3 will be used in the analysis programme.

These samples include:

i) barley as a monocrop
ii) two varieties of barley: 1) the high-lysine barley, Lysiba and 2) Otira
iii) two varieties of peas: 1) Bohatyr and Agadir
iv) Pea, lupin and fababean as alternative grain legumes

Decisions on analyses will be made throughout the experimental period based on information on:
Effect of soil: Sandy loam soil (Højbakkegaard) and coarse sandy soil (Jyndevad)
Effect of intercropping
Effect of N fertilisation
Effect of K fertilisation
Effect on yield
Effect of climate and other growing conditions during three growing seasons.

The analyses will be initiated when all information from the first growing season have been collected and evaluated. Due to a very limited budget for analyses, they will be performed step-wise. Initially, analyses will be based on N determinations. From these results, samples for more detailed chemical analyses will be selected and, finally, samples for analyses of biological responses, using a standardised rat model, will be selected.

E. Project publications (publications in *italics* are only partly due to this project)

Articles in international, scientific journals with review procedures

Hauggaard-Nielsen H and Jensen E S (2001). Genotype effects in relation to pea and barley performance in intercropping systems. Field Crops Research, 72 (3) pp. 185-196

Hauggaard-Nielsen H, Ambus P and Jensen E S (2001). Interspecific competition, N use and interference with weeds in low input pea-barley intercropping. Field Crops Research, 70 (2) pp. 101-109

Hauggaard-Nielsen H, Ambus P and Jensen E S (2001). Temporal and spatial root distribution and competition for nitrogen in pea-barley intercropping – a field study using ^{32}P methodology. Plant and Soil, 236 (1) pp. 63-74

Hauggaard-Nielsen H, Ambus P and Jensen E S (2002). Nitrate leaching and N balance in cropping systems with sole or intercropped pea and barley. Nutrient Cycling in Agroecosystems, submitted.

Presentations at congresses, symposiums etc.

Hauggaard-Nielsen H., Ambus P. and Jensen E. S. (2001). Reintroducing grain legume-cereal intercropping for increased protein production in European cropping systems. Proceeding til 'The 4th European Conference on grain legumes: Towards the sustainable production of healthy food, feed and novel products'. 8 - 12 July, Cracow, Poland. Udvalgt til oral præsentation

H. Hauggaard-Nielsen, M.B. Peoples, M.K. Andersen, A.H. Nielsen and E.S. Jensen (2001). Using farmers' fields to investigate pea-barley intercrop dynamics in low-input agriculture. Poster og short paper til konferencen '11th Nitrogen Workshop', 9 - 12 September, Reims, France.

Jørnsgård B., Raza S., Jensen E.S. and Christiansen J.L. 2001. Choise of species and varieties of grain legumes and cereals for inter - and mono cropping in organic agricultural systems. Proceedings of the 4th European Conference on Grain Legumes, Cracow, Poland, p350.

Articles in agricultural journals etc.

Other presentations at meetings, field days et.

29. August 2001. Slagelse Tekniske skole, field visit
22. June 2001. Delegation from Bangladesh, field visit
20. June 2001. Åbent hus på Jyndevad….Field visit.

Jensen, E. S. og Hauggaard-Nielsen. H. 2001. Valg af frøbælgplantesorter for dyrkning i økologisk jordbrug. FØJO workshop om forædling af korn og bælgsæd i økologisk jordbrug, Foulum, Maj 2001

Jensen, E.S. 2001 Grain legumes in organic farming systems. AEP/LINK meeting, Bologna, April 2001.

Jørnsgård B 2001. Erfaringer med dyrkning og kvalitet af lupin. Oral presentation and abstract . Efterårskonference Hotel Nyborg Strand: 56-57.

Jørnsgård B. 2001. Proteinafgrøder - status og potentiale. På Ideforum for planteavlsudvikling og –forskning. Landbrugets Rådgivningscenter, Skejby, 19 april 2001. Oral presentation and abstract.

Muguerza, N. B. 2001. Interference in pea, barley, oilseed rape intercrops during early growth stages. MSc thesis, June 2001, KVL.

F. Scientific education (ph.d. and post doc.), including visiting scientists and visits abroad

WP3:
The task 2 and some of the aspects in task 3 was performed in collaboration with PhD-student Mette Klindt Andersen, Institute of Agricultural Sciences, Agrovej 10, DK-2630 Taastrup

Visiting scientists:
Dr. Graeme Schwenke, NSW Agriculture, Tamworth Centre for Crop Improvement, NSW 2340, Australia. Graeme.schwenke@agric.nsw.gov.au

Dr. Ian Fillery, CSIRO Centre for Mediterranean Agricultural Research, Private Bag, PO Wembley WA 6014, Australia. I.Fillery@ccmar.csiro.au

G. National and international co-operation

National

Collaboration with other research projects and scientist in the previous and the new DARCOF programme is expected, especially the on-going project, “Crop rotations for cereal production in organic farming”. Project leaders: Askegaard, M.A. Olesen, J.E., Rasmussen, I.R. (Part of the activities under Danish Research Centre for Organic Farming).Project application (I.10, DARCOF) “Organic vegetable production methods, and the use of catch crops to improve the production and protect the environment”. Project leader: Kristian Thorup-Kristensen.

Modelling intercrops: Jørgen Berntsen, Department of Crop Physiology and Soil Science, P.O. box 50, DK-8830 Tjele. Jorgen.Berntsen@agrsci.dk.

International

MA participates in a Nordic working group focusing on potassium in organic farming.

In his position of member of the scientific committee of The European Association of Grain Legume Research (AEP), ESJ has strong links with European scientists within all disciplines of grain legume research (Prof. Yves Crozat, ESA, Angers; Prof Jacques Wery, INRA, Ftance)

ML and colleagues participates in the COST Action 817: “Population studies of airborne pathogens on cereals as a means of improving strategies for disease control”. In this CA groups work with organic farming systems, incl. The role of increased crop diversity