



## Status Report 2003 and Application for Continuation in 2004

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

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### 1. Research program

Research in organic farming 2000-2005 (DARCOF II)

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### 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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### 3. Head of project

Erik Steen Jensen (ESJ), Department of Agricultural Sciences, The Royal Veterinary and Agricultural University, Højbakkegård Alle 13, DK-2630 (-31.7 2003) (From 1.8.2003) Plant Research Department, Risø National Laboratory, DK-4000 Roskilde. Phone: +45 4677 4108, Fax: +45 46774260. Email: erik.s.jensen@risoe.dk

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### 4. Participating institutes

The Royal Veterinary and Agricultural University (KVL)  
Bülowsvej 17, 1870 Frederiksberg C  
Phone: 35282828, Fax: 35282828

Danish Institute of Agricultural Sciences (DJF)  
Research Centre Foulum  
Postbox 50, 8830 Tjele  
Phone: 89991900, Fax: 89991699

Risø National Laboratory (RISØ)  
Frederiksborgvej 399  
Postbox 49, 4000 Roskilde  
Phone: 46774677, Fax; 46775688

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## 5. Other project staff

### **KVL (Department of Agricultural Sciences)**

Assistant professor Ph.d. Henrik Haugaard-Nielsen (HHN),  
Organic Farming Unit  
Højbakkegård Alle 13, DK-2630 Tåstrup  
(until 31.7.2003).

Research assistant, M.Sc. Marie Trydeman Knudsen (MTK)  
Organic Farming Unit  
Højbakkegård Alle 13, DK-2630 Tåstrup  
(until 31.8.2003).

Assistant professor Bjarne Jørnsgaard (BJ),  
Section of Plant Breeding and Crop Science,  
Thorvaldsensvej 40, 1871 Frederiksberg C,  
Phone: 35283463, Fax. 35282175, E-mail: [bj@kvl.dk](mailto:bj@kvl.dk)

### **Risø, Plant Research Department**

Scientist, Ph.d. Henrik Haugaard-Nielsen (HHN), (from 1.8.2003)  
Plant Research Department,  
Risø National Laboratory, DK-4000 Roskilde.  
Phone:+45 4677 4113, Fax : +45 4677 4260.  
Email: [Henrik.haugaard-Nielsen@risoe.dk](mailto:Henrik.haugaard-Nielsen@risoe.dk)

Research assistant, M.Sc. Marie Trydeman Knudsen (MTK) (from 1.8.2003)  
Plant Research Department,  
Risø National Laboratory, DK-4000 Roskilde.  
Phone:+45 4677 4157, Fax : +45 4677 4260.  
Email: [Marie.trydeman.Knudsen@risoe.dk](mailto:Marie.trydeman.Knudsen@risoe.dk)

Senior scientist Michael Lyngkjær (ML)  
Department of Plantbiology and Biogeochemistry,  
Postbox 49, 4000 Roskilde  
Phone: 46774133, Fax. 46774122, E-mail: [M.lyngkjaer@risoe.dk](mailto:M.lyngkjaer@risoe.dk)

Senior scientist Per Ambus (PA)  
Plant Ecosystems and Nutrient Cycling  
Postbox 49, 4000 Roskilde  
Phone. 46774152, Fax. 46774160, E-mail: [Per.ambus@risoe.dk](mailto:Per.ambus@risoe.dk)

Post.doc Julia Kinane (JK)  
Resistance Biology Programme  
P.O. Box 49, 4000 Roskilde  
Phone: 4677 4195 Fax: +45 4677 4282, E-mail: [Julia.Kinane@risoe.dk](mailto:Julia.Kinane@risoe.dk)

### **Danish Institute of Agricultural Sciences (DJF)**

Scientist Margrethe Askegaard (MA)  
Department of Crop Physiology and Soil Science  
Postbox 50, 8830 Tjele

Phone: 89991702, Fax. 89991619, E-mail [Margrethe.Askegaard@agrsci.dk](mailto:Margrethe.Askegaard@agrsci.dk)

Professor Knud Erik Back Knudsen (KEBK),  
Department of Animal Nutrition and Physiology  
Postbox 50, 8830 Tjele

Phone. 89991143, Fax. 89991166, E-mail: [Knuderik.backknudsen@agrsci.dk](mailto:Knuderik.backknudsen@agrsci.dk)

Senior scientist Sigurd Boisen (SB)  
Department of Animal Nutrition and Physiology  
Postbox 50, 8830 Tjele

Phone. 89991145, Fax. 89991166, E-mail [Sigurd.Boisen@agrsci.dk](mailto:Sigurd.Boisen@agrsci.dk)

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## **6. Project period (month, year)**

Start of project: September 2000

End of project: December 2003

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## **7. Midterm description of the project, its results and progress, and application for continuation in 2004**

### **A. Project summary**

There is an urgent requirement for an increased local/on-farm production of protein and cereal crops in Danish and European organic farming system to meet the increasing demand for the feeding of monogastric animals (pigs and poultry). Grain legumes, such as pea, fababean and lupins, and cereals can complement each other in animal feeds and these grain legumes are the best-suited species for 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<sub>2</sub> 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<sub>2</sub> 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

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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**

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

\* Responsible participants are underlined

## B. Objectives and expected achievements

### WP1. 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.

### WP2. 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 extent differences exist between grain legume species and varieties in recovering and utilising P from soils low in available P.

### **WP3. 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.

### **WP4. 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.

### **WP5. 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.

## **C. Midterm results and progress**

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

#### **WP1. Grain legumes for mono- and intercropping in organic farming systems**

##### **Task 1: Screening potential genotypes for sole- and intercropping**

No activities 2003

##### **Task 2. Production, yield variability, nitrogen fixation and quality of grain legumes on two soil types.**

The experiment was carried out at the locations Højbakkegård and Jyndevad in year 2001, 2002 and in 2003. Fababean, lupin, a semi-leafless and a normal leafed pea variety and a standard feed barley and a high lysine variety were grown as sole crops at standard sowing rate, and the barley varieties were intercropped with the different legumes in 1:1 mixtures (see WP3). After emergence of the cereals and legumes ryegrass was under sown to catch nitrogen during autumn and winter. The development, including the time of key development stages and plant heights in sole crop and in intercropped plot was followed during the growing season. At maturity one m<sup>2</sup> were hand harvested in all plots for determination of yield nitrogen content, grain size and N fixation by the <sup>15</sup>N natural abundance method. The samples are currently being analysed. See also WP3 task 1.

##### **Task 3. Ideotypes for intercropping and weed suppression ability**

No activities 2003

#### **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.**

Four different crops/intercrops (barley, pea/barley, field bean and lupin) were tested at two different levels of K (0K and 80 kg K ha<sup>-1</sup>) in two years (2001 and 2002, table 1) and the residual effect was measured in a subsequent crops (2002 and 2003). The 0K treatment represents a low K status system with 2-3 mg exchangeable K 100 g soil<sup>-1</sup>. This level is below the average level in cropping systems receiving manure. The residual effect of K treatments in the second experiment was evaluated in the 2003 growth season, which passed without major problems. The yields for 2003 will

first be estimated in November.

Table 1. Main crop yields 2001 and 2002 (t DM ha<sup>-1</sup>)

Crop	2001		2002	
	0K	80K	0K	80K
Barley	2 <sup>a</sup>	2.4 <sup>a</sup>	2.7	3.4
Per/barley	2.4 <sup>a</sup>	3.4 <sup>b</sup>	2.9	3.9
Barley	1.0 <sup>a</sup>	1.2 <sup>a</sup>	2.0	2.1
Pea	1.4 <sup>b</sup>	2.2 <sup>a</sup>	0.9	1.8
% pea	58	65	31	46
Lupin	1.2 <sup>a</sup>	1.2 <sup>a</sup>	2.1	2.2
Field bean	2.6 <sup>b</sup>	3.6 <sup>a</sup>	2.9	4.0

Precrop effects of the barley, pea/barley, field beans and lupines grown in 2001 and measured in spring barley in 2002 corresponded to 541, 713, 1081 and 1226 kg DM ha<sup>-1</sup> in the 0K treatment, respectively. Application of K in 2001 increased the 2002 yields slightly, whereas use of catch crops, tested in barley and lupines, increased yields by more than 100%.

The following preliminary conclusions based on 2001 and 2002 results can be drawn:

- Yields were greatest in field bean and the pea component in the pea/barley with K application.
- Despite a very low level of exchangeable K, 2-3 mg K 100 g soil<sup>-1</sup>, the yields of lupine did not increase with K application.
- A considerable K-uptake, which exceeded 200 kg ha<sup>-1</sup>, came from the layer below 20 cm or from "non-exchangeable" fractions.
- Measurements of soil pH did not show any decrease during the growing season as it was expected for the N<sub>2</sub>-fixing crops.
- In the literature it is normally assumed that the crop K-content has its maximum at flowering, however the net K-uptake continued over a longer period after this point.
- Visual symptoms on K deficiency did first occur at flowering in the pea where some of the flower buds died. In the field beans the symptoms of K deficiency appeared late and as a retarded growth.

## **Task 2. Quantification of the P uptake of different grain legume species, cereals and their intercropped mixtures to estimate their performance at low soil P levels.**

In agreement with the DARCOF management the field experiments were replaced by greenhouse pot experiments. The first was finished in June 2003, and the second is running and will be finished in December 2003. The growth of pea, fababean, and lupin was tested at 3 different soil P levels, respectively 5, 15 and 45 ppm soil available P in respectively pure stands and in mixture with barley in a replacement design. The plants were harvested 9 weeks after sowing and biomass, plant P and N analysed and root length and mycorrhiza colonization measured. The legume species showed great difference in growth, P uptake and N fixation at varying P soil levels, which presumably can be ascribed to different uptake strategies such as increased root development, symbiosis with mycorrhiza, or exudation of acid from the roots.

Faba bean and peas doubled their biomass with increasing P soil level, whereas lupin and barley were unaffected. The lack of response of barley could be an indirect effect of soil N being the most limiting factor, whereas the lack of response in lupins, being a nitrogen fixing plant, must be ascribed to less sensitivity. Root length and

mycorrhiza colonization were largest at low P levels in faba beans and peas, whereas root length was unaffected and as expected no mycorrhiza colonization was found in lupins. The P concentration in plant dry matter increased significantly in lupins, whereas it remained relatively unaffected in peas and faba beans.

The effect of intercropping with barley was species specific for the three legumes. In mixtures the response in biomass to soil P was similar, but less significant than in pure stands. There were significant benefits of intercropping especially at low soil P levels for fababeans and peas where the LER values (land equivalent ratio) for biomass and total plant P ranged from 1.32 to 1.70. At higher soil P levels for faba bean and pea mixtures and at all soil P levels for lupin mixtures the LER values were reduced but still significantly larger than 1.0 (Table 2). A LER value of 1.30 indicates an advantage of 30% from intercropping.

Preliminary it can be concluded that mixtures of grain legumes with barley appear most beneficial at low soil P level and that the response is more pronounced for peas and fababeans.

Table 2. LER values for biomass and total P content in plant aerial biomass in mixtures of peas, fababean and lupins with barley at varying soil P levels.

Land Equivalent ratio (LER)						
	0 ppm P		15 ppm P		45 ppm P	
	Biomass	Total P	Biomass	Total P	Biomass	Total P
Barley + peas	1.44	1.32	1.35	1.33	1.12	1.15
Barley + faba bean	1.70	1.32	1.27	1.16	1.07	1.09
Barley + lupin	1.18	1.19	1.23	1.09	1.23	1.15

### **WP3. Intercropping of grain legumes and cereals: resource use and weed management**

**Task 1:** This task is conducted in collaboration with WP1 regarding the stability of grain legumes yields in sole crops and intercrops at two locations in Denmark. The third-year experiment was carried out at Højbakkegård in Tåstrup and Jyndevad in 2003. The project has shown that the grain legume-cereal intercrops use environmental sources for plant growth more efficiently than the respectively sole crops, independent of species and soil type. The grain N concentration in barley intercropped with grain legumes increases compared to the respective sole crops independent of fertilization. Furthermore, the proportion plant N derived from fixation in intercropped grain legumes are increased compared to the respective sole crops. However, the amount of N<sub>2</sub> fixation by intercropped grain legumes is positively correlated to the final yield proportion in the intercrops. More specific recommendations dealing with the different species and differentiation of soil type, cropping and quality aspects will be conducted using the complete 3-year dataset analysis, which is available later in 2003.

In 2002 the succeeding spring sown oats showed no significant differences either between sites or treatments judged by measured oat yields (in average 400 g grain DM m<sup>-2</sup>). A slightly greater grain yield (450 g grain DM m<sup>-2</sup>) on the sandy loam soil was achieved in 2003. The 2003 yield data and chemical analysis from the sandy soil is still being processed.

### Task 2:

In this task we analysed the effect of intercropping of grain legumes on the the capture of other plant growth resource sin the field, such as light, soil water, P and K.

Specific light absorption patterns by sole and intercropped pea and barley including weeds were performed in 2003 using light meter readings while removing the crops successively. Preliminary analysis of the results show that sole cropped pea absorb the same percentage of light as barley in early growth phases followed by a later reduction caused by increased weed absorption capacity (Fig. 1). In the intercrop early light absorption by barley strongly reduced the proportion absorbed by pea. Barley leaf area seems to determine the interspecific competitive ability of this species towards component crops and weeds in a crop stand.

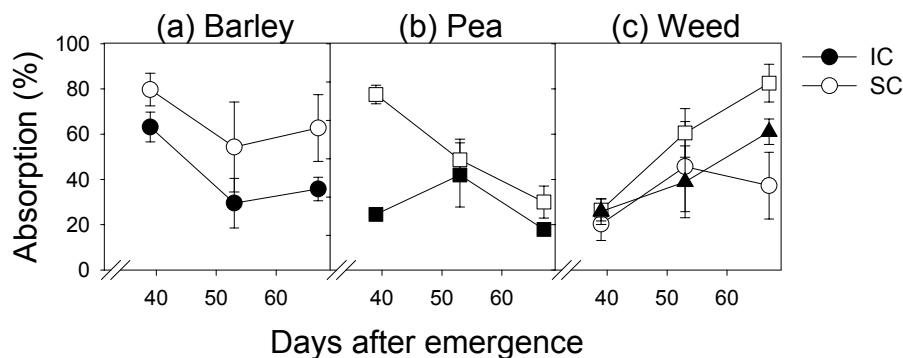


Figure 1. Relative absorption of light (%) in sole cropped (SC) and intercropped (IC) pea and barley including weeds, measured by light meter and successive harvest in the crop stand three times during the growing season 2003. Values are means ( $n=4$ )  $\pm$  SE.

Using the simulation model FASSET on a pea-barley dataset it was concluded that the vertical distribution of barley leaf area had a great influence on the outcome of the interspecific competition between pea and barley crops.

Aboveground phosphorous and potassium accumulation will be measured in plant samples of sole cropped pea and barley and of 50%:50% and 100%:50% pea-barley intercrops, the analysis will be conducted medio November. Continuous water measurements (once a week) throughout the growing season were also performed. However, due to no water limitations during the growing season no major conclusions can be drawn.

**Task 3:** The effect of pea or lupin intercropping with barley at two levels of N availability on crop-weed dynamics was studied in 2002. The weed dry matter accumulation early in the growing season was significantly reduced in the grain legume-barley intercrops relative to the respective grain legume sole crops in the Højbakkegård 2002 trial. The weed DM accumulation 36 days after emergence (DAE) was positively correlated with the topsoil (0-25 cm) nitrate concentration 22 DAE (Fig. 2a). Furthermore, a linear negative correlation between leaf area index (LAI) 22 DAE and weed DM 36 DAE was found independent of application of  $0.5 \text{ g N m}^{-2}$  (Fig. 2b). Thus, improved competitive ability towards weeds during early growth stages may be determined by both a greater uptake of inorganic N and a greater leaf area.

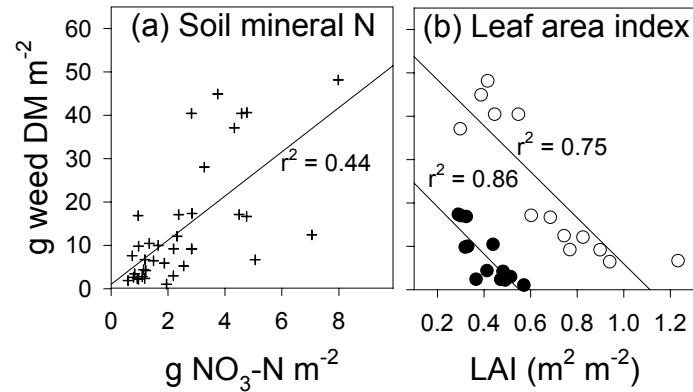


Figure 2. Weed dry matter accumulation (DM) 36 days after emergence in relation to soil mineral N (a) and leaf area index (LAI)(b) measured 22 days after emergence. Regression lines are shown for the total soil mineral N dataset (a) but separated in with application of 5 g urea-N m<sup>-2</sup> (open symbols) or without (closed symbols) N application for LAI (b). Each symbol represents a single observation of pea sole crop (SC), lupine SC, barley SC, pea-barley intercrop (IC) or lupine-barley IC.

The effects of increasing species diversity from one sole cropped up to four intercropped species of pea, faba bean, lupin and barley were studied on a sandy loam soil at Højbakkegård using replacement design. There was a tendency to a decreased weed biomass yield when increasing the number of species in the intercrop. However, an increase in species number did not increase the crop dry matter per se. Species composition was more important for yields than species number. It was observed that an additional component could change the relation of strength between the “initial” components via its positive or negative effect on the crop stand complementarity.

#### **WP 4. Plant health in grain legumes and cereal crops**

##### **Task 1.**

The effect of barley-legume intercrop on disease incidence was investigated over three years in two locations (Højbakkegård and Jyndevad). Results from the third year are currently being analysed. Over the three year period several diseases have been observed: ascochyta blight (*Mycosphaerella pinodes*) on pea, brown leaf spot (*Plieochaeta setosa*) and mould (*Botrytis*) on lupin and chocolate spot (*Botrytis*) and rust (*Uromyces fabae*) on bean. On barley net blotch (*Pyrenophora teres*), brown rust (*Puccinia hordei*) and powdery mildew (*Blumeria graminis* f. sp. *hordei*) were detected. While the results from 2003 have not yet been fully analysed, they appear to follow the trends from the previous two years whereby a general reduction in disease was observed in all intercrop systems compared to the corresponding monocrop. The magnitude of the reduction varied according to 1) dispersal mechanism of the diseases, 2) height of the crops, 3) anatomy of the accompanying crop e.g. full leaf pea gave larger reduction than semi-leafless pea and 4) the number of crops (components) within the intercrop.

The above monocrop and intercrop systems were also grown with 50 kg N (2001, 2002 & 2003) or 100 kg N (2003) added as urea and monitored under the same field conditions. The presence of added nitrogen increased levels of mildew and rust (biotrophic fungi). Added N influenced the intercrop effect on net blotch. In the presence of added N the reduction in net blotch was significantly less than when no extra N was added.

**Task 2.**

Glasshouse experiments on the effect of the availability of N, P or K on disease resistance mechanisms in barley were set up. Barley plants depleted in N, P or K were inoculated with powdery mildew. Subsequently, plants were scored for disease and fungal development was monitored. Plants depleted of N reduced both penetration of powdery mildew and subsequent colony size. Minimal levels of plant P increased infection by the fungus but the resulting colonies were smaller than the control. Low K levels in the plant increased fungal penetration, but had no effect on colony size. Since N and K had the greatest overall effect on powdery mildew we subsequently focussed on these two nutrients. Barley was grown either as a sole crop or in an intercrop with peas and the effect of N and K supplied in factorial combinations on powdery mildew severity was examined. N and K concentrations in the inoculated leaves were also measured.

When barley was grown as a sole crop at very high and very low N concentrations, K had no significant influence on powdery mildew severity. Whereas at normal N levels, the effect of K was seen in the deficiency range. Initial results when barley was grown in an intercrop with pea indicate that there are interactions between the two crops with respect to N (especially when grown at the deficiency levels). This in turn influences susceptibility on powdery mildew in barley.

**Conclusions**

1. Barley grain legume intercropping reduced disease incidence. 2. The presence of added N decreased the magnitude of this reduction for one disease. 3. Added N increased incidence of biotrophic pathogens. 4. All three major nutrients (N, P & K) in isolation affected powdery mildew development, with N and K having the greatest overall effect. 5. There is evidence of interactions between N and K influencing plant health. 6. Barley and pea interact in the intercrop with respect to N, which in turn influences plant health.

**WP5. Quality aspects and isotopic analysis**

The nutritional quality of seeds from the two first growing seasons (2001 and 2002, respectively) of sole and intercrops of cereals and legumes has been investigated. The seeds were analysed for ash, crude protein, crude fat, starch and enzyme digestible organic matter. Furthermore, the effect of protein level on amino acid composition in each crop was investigated.

The results show that intercropping has a general positive effect on the protein content of barley. However, the content of the different nutrients showed a considerable variation in several of the investigated crops. Thus, the protein content in barley was lower in 2002 (8-13%) than in 2001 (10-15%). Extra N supply to sole crops of barley resulted in an increased yield, but not in a clear positive effect on protein content in the seed. On the other hand, intercropping of barley with legumes resulted in a clear positive effect on the protein content in normal barley as well as the high-lysine barley. However, the effect was very variable and influenced by year, location and barley cultivar.

Starch content in barley was, on the contrary, generally lower in barley kernels from inter-cropping. Crude fat concentration was also slightly lower in barley from inter-cropping. However, a rather high variation was observed (2.1 to 3.7% in the normal

variety and 3.6 to 5.5% in the high-lysine variety).

## C.2 Fulfilment of deliverables and milestones

<b>WP 1 Evaluation of potential of grain legumes for mono- and intercropping with cereals</b>	<b>Time schedule according to application</b>	<b>Deviations, if any*</b>
<b>Task</b>		
1. Screening of potential genotypes	2000-2001 Done	
2. Production, yield variability, nitrogen fixation and quality of grain legumes on two soil types	2001-2003	
3. Ideotypes for intercropping	2001-2002	
<b>Deliverables</b>		
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 Done	
2 Genotypic characteristic for good intercropping and weed suppressing ability.	2003	
3. Paper on yield variability and N <sub>2</sub> fixation in grain legumes on two soil types	2003	
4. Paper on grain legume genotypes for intercropping and weed suppression	2002 proceedings published, paper for scientific journal under preparation	
<b>Milestones</b>		
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 ideotypes of narrow-leaf lupin for intercropping or weed management.	2003	
<b>WP2 Performance of grain legumes and cereals at low and low P and K levels</b>	<b>Time schedule according to application</b>	<b>Deviations, if any*</b>
<b>Task</b>		
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 on the crop performance and P uptake at low levels of P	2001-2003	
<b>Deliverables</b>		
1. Paper on the effect of low K-status on protein production on a coarse sandy soil submitted to international refereed journal.	2003	*1
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	*2
<b>Milestones</b>		
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 done	
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	*2

5. Recommendation for species/genotype choice at low P status soil	2003	*2
<b>WP3 Intercropping of grain legumes and cereals</b>	<b>Time schedule according to application</b>	<b>Deviations, if any*</b>
<b>Task</b>		
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	
<b>Deliverables</b>		
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	*
<b>Milestones</b>		
1 Results from field experiments year 1	ultimo 2001 Done	
2 Results from field experiments year 2	ultimo 2002 Done	
3 Results from field experiments year 3	ultimo 2003	
<b>WP4 Disease resistance in relation to intercropping and nutrient uptake</b>	<b>Time schedule according to application</b>	<b>Deviations, if any*</b>
<b>Task</b>		
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 ( <i>Blumeria graminis</i> f.sp. <i>hordei</i> ) and pea attacked by <i>Mycosphaerella pinodes</i> , one of the three phytopathogenic fungi causing <i>Ascochyta</i> blight on pea.	01/2001-08/2002	
2 Characterise possible influence of intercropping on disease resistance mechanisms in individual host plants (barley / <i>B. graminis</i> and pea / <i>M. pinodes</i> ) 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 / <i>B. graminis</i> and pea / <i>M. pinodes</i> ).	04/2001-07/2003	
4 Monitoring diseases in field plots described in WP2 and WP3.	04/2001-07/2003	
<b>Deliverables</b>		
1 D14.Paper about intercropping and disease resistance	2002 Done	*1
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	
<b>Milestones</b>		
1 Paper about intercropping and disease resistance (December 2002)	2002 Done	
2 Paper about influence of nutrient uptake on disease resistance (May 2003)	2003	*2
<b>WP5 Quality of grain legumes and cereals and isotopic analysis</b>	<b>Time schedule according to application</b>	<b>Deviations, if any*</b>

<b>Task</b>		
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. Identification of possible antinutritional factors in grain legumes	2002-2003	
4. Quality of wheat for bread	2003	
5. Staple isotopes	2002-2003	
<b>Deliverables</b>		
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 Done Jan 2003 Done Dec 2003	
<b>Milestones</b>		
Evaluation of variation in total nitrogen from the screening study	2002 Done	
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 in D

## **D. Description of deviations and subsequent adjustments of plans**

### **WP. 2**

\*1The main part of the results will be analysed ultimo 2003 and further in the start of 2004 (application for transfer of 2 research month from the budget in 2003 to 2004).

\*2The first greenhouse experiment on P was finished in June 2003 and the second and last will be harvested in December 2003, and the chemical analysis performed primo 2004. Therefore we propose a prolongation of these project activities until March 2004. The deliverables are ready March 2004 if the project will be prolonged three months into 2004.

### **WP. 3.**

\*The papers will be delayed until March 2004 if the project is prolonged into 2004. Additional analyses on baking quality in wheat will be performed as a response to intercropping with grain legumes.

### **WP. 4**

\*1Paper about intercropping and disease resistance has already been published There will be an additional paper about intercropping and disease resistance, submitted by the end of the project period (December 2003) or soon after.

\*2 Paper about influence of nutrient uptake on disease resistance is in preparation and will be submitted before the end of the project period.

### **WP. 5**

Papers to be delivered in 2004 according to the new project finalization.

## **E. Project publications and other products**

### 1. Articles in international, scientific journals with review procedures

\*Bellostas, N., Hauggaard-Nielsen, H., Andersen, M.K. and Jensen, E.S. 2003. Early interference dynamics in intercrops of pea, barley and oilseed rape. *Biological Agriculture and Horticulture* (In press).

\*\*Hauggaard-Nielsen H, Ambus P and Jensen E S (2003). The comparison of nitrogen use and leaching in sole cropped versus intercropped pea and barley. *Nutrient Cycling in Agroecosystems* 65, 289-300

\*\*Hauggaard-Nielsen H and Jensen E S (2001). Evaluating pea and barley cultivars for complementarity in intercropping at different levels of soil N availability. *Field Crops Research* 72, 185-196.

\*\*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 employing <sup>32</sup>P methodology. *Plant and Soil* 236, 63-74.

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

\*\*Jensen E S and Hauggaard-Nielsen (2003). How can increased use of biological N<sub>2</sub> fixation in agriculture benefit the environment? *Plant and Soil* 252, 177-186.

\*\*Neergaard A. de, Hauggaard-Nielsen H., Jensen L. S., and Magid J. (2002). Decomposition of

whiteclover (*Trifolium repens*) and ryegrass (*Lolium perenne*) components: C and N dynamics simulated with the DAISY soil organic matter submodel. *European Journal of Agronomy* 16, 43-55.

Kinane, J. and Lyngkjær, M. (2002). Effect of barley-legume intercrop on disease frequency in an organic farming system. *Plant Protection Science* 38 (Special Issue 1): 227-31

## 2. Papers presented at congresses, symposiums, etc.

Hauggaard-Nielsen, H. B. Jørnsgaard and E. S. Jensen 2003 Legume-cereal intercropping as a weed management tool. Proceedings of European weed research society working group "Crop/weed interactions, April 10-12, Università Tuscia, Viterbo, Italy.

Hauggaard-Nielsen, H. 2002. Grain legumes in organic cropping systems. Proceedings of Clustered workshop meeting presented at the workshop "Towards European expertise on management of cropping systems including legumes, 27-28 September, Strasbourg, France

Hauggaard-Nielsen, H., Ambus, P., Jensen, E.S. 2001. Reintroducing grain-legume cereal intercropping for increased protein production in European Cropping systems. Proceedings of AEP, 4<sup>th</sup> Conference, July 2001, p. 52-53. Crakow, Poland,

Hauggaard-Nielsen, H., Peoples, M.B, Andersen, M.K., Nielsen, A.H. and Jensen, E.S. 2001. Pea-barley intercrop dynamics in farmers fields. 11<sup>th</sup> Nitrogen Workshop, Reims, France, 10-12 September 2000

\*\*Jensen, E.S. 2003. Organic agriculture – the Nordic, European and global perspectives. In: Proceedings of the NJF's Congress: Nordic agriculture in global perspective. p. 190-193, Tampere University Print, Tampere.

Jensen, E.S., Mørkeberg, A., Sørensen, H. and Sørensen, S. 2001. Effects from intercropping of pea and barley on the contents of proteins and bioactive molecules in the seed. Proceedings of AEP 4<sup>th</sup> Conference, July 2001, .p. 90-91. Crakow, Poland.

\*\*Joernsgaard B., J. L. Christiansen and N. Kuptsov. 2002 .Adaptation of lupins for Northern European maritime conditions. Proceedings of the international Lupine Conference, Island June 2002. submitted/in press

Jørnsgård, B., Raza, S., Jensen, E.S., Christiansen, J.L. 2001. Choice of species and varieties of grain legumes and cereals for inter- and monocropping in organic agricultural systems. Proceedings of AEP 4<sup>th</sup> Conference, July 2001, Crakow, Poland. p. 350.

\*\*Kristensen L., Østergård H. og Jørnsgård B. 2001. Forædlingsmål og forædlingsopgaver i økologisk korn og bælgssæd. I Forædling af korn og bælgssæd samt produktion af såsæd i økologisk Jordbrug. Eds Nielsen B.J. og Lars C. FØJO-rapport nr 15/2001, Forskningscenter for Økologisk Jordbrug, pp 109-137.

\*\*Kristensen L., Østergård H. og Jørnsgård B. 2001. Sortsafprøvning i korn og bælgssæd i økologisk jordbrug. I Forædling af korn og bælgssæd samt produktion af såsæd i økologisk Jordbrug. Eds Nielsen B.J. og Lars K. FØJO-rapport nr 15/2001, Forskningscenter for Økologisk Jordbrug, pp 141-161.

Kinane, J. 2002. Effect of Barley-Legume Intercrop and Major Nutrients on Disease Frequency in an Organic Farming System. Disease Resistance in Plant Pathology. 6th Conference of European Foundation for Plant Pathology 9-14 September 2002, Prague, Czech Republic.

Kinane, J. 2003. Effect of Barley-Legume Intercrop and Major Nutrients on Disease Frequency in an Organic Farming System. ICPP (International Congress for Plant Pathology) 8<sup>th</sup> International Congress for Plant Pathology, 2-7<sup>th</sup> February, Christchurch, New Zealand.

## 3. Reports, articles in agricultural journals, etc.

\*\*Carrouee, B., Ellis, N., Jensen, E.S. and Schneider, A. 2002. The benefits of grain legumes for an envi-

ronment-friendly and sustainable European agriculture. Grain Legumes 36,

Hauggaard-Nielsen H., Knudsen, M. T. and Jensen E. S. 2003 Del og hersk. Økologisk Jordbrug, juni

Hauggaard-Nielsen, H., Jørnsgaard, B. Jensen, E.S. 2002. Arealet med frøbælgplanter bør øges. Landsbladet, Januar

\*\*Jensen, E. S. and Hauggaard-Nielsen H 2002 Understanding the role of grain legumes in the N cycling of agroecosystems. Grain Legumes 36, 12-14

\*\*Jensen, E.S. 2002 Økologisk dyrkning af linser i Danmark? Økologisk Jordbrug 2002

\*\*Jensen, E.S. 2002 Økologisk Jordbrug, fødevarer og miljøet. Debat indlæg (Synspunkt) om økologisk fødevarer i Søndagsavisen d. 9.6. 2002, s. 2

\*\*Salon C. and Hauggaard-Nielsen, H. 2001. Managing crop nitrogen and soil dynamics. Grain Legumes 34: 18-19.

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

##### Field days

Askegaard, M. 2002. Many people (mostly farmers and advisors) visited the WP2 task 1 field experiment during the growing season. Furthermore the experiment was presented at a field-course for advisors. June.

Hauggaard-Nielsen 2003. Field visit and general discussion focusing on grain legume-cereal intercropping potentials with special interest in wheat bread making quality aspects on a local farmers field day at Andre Lassen, Felsted, Åbenrå (60 farmers participated) arranged by the Danish National Organic Union (Økologisk Landsforening), July.

Hauggaard-Nielsen H 2003. Farmers visit (16 farmers) from local advisory center (Agrogården, Ringe) requested by Advisor Richard de Visser to introduce and discuss present field experiments according to practical assessments and future perspective for grain legume-cereal intercropping to secure sufficient protein production to be self-sufficient in 2005, June

Hauggaard-Nielsen H 2003. Presentation of field activities and research objectives for 25 Selandia College students on a DANIDA funded brush-up course on plant production, June

Hauggaard-Nielsen H. 2002 Field day at Jyndevad Experimental Station, Danish Institute of Agricultural Sciences presenting the GENESIS trial for local farmers and advisors in the southern part of Jutland, June

Hauggaard-Nielsen H. 2002 Visit from Danish Institute of Agricultural Sciences field staff responsible for organic trials at Foulum, Jyndevad and Flakkebjerg Experimental stations, June

Hauggaard-Nielsen H. 2002 Visit from The Danish Family Farmers' Association on Sealand showing organic farmers the GENESIS activities, June

Hauggaard-Nielsen H. 2003 Visit from the Swedish University of Agricultural Sciences (SLU) KANCELLI to see GENESIS field activities, May

Hauggaard-Nielsen H. and Jørnsgaard B 2002 Participating on a field day arranged by DLG-Økologi for farmers interested in organic protein production emphasizing significant characteristics with grain legume cropping while visiting farmers fields.

Jensen, E.S. 2003 Økologi, diversitet og bæredygtigt – besøg af Landsforeningen Grønne Familier på KVL. Besøg ved Bakkegården og Genesisforsøg, juli 2003.

Jensen, E.S. 2003. Crop diversification and organic agriculture. Besøg af det Tyske Selskab for Øko-

logi med diskussion og fremvisning af forsøg i marken på KVL Taastrup, juni 2003.

Jensen, E.S. 2002 Development and research within organic farming in Denmark. Field Day for Farmers, Arranged by CSIRO, Canberra and NSW Agriculture, Oktober

Knudsen M. T. August 2003 Field visit and hands-on demonstration of GENESIS activities for 50 Agrotechnology students from Selandia (Slagelse Tekniske Skole).

Knudsen M. T. 2003 Field visit and hands-on demonstration of GENESIS activities for 50 Agrotechnology students from Selandia (Slagelse Tekniske Skole).

Knudsen, M.T. and Hauggaard-Nielsen H. May 2003. Introduction to key issues according to grain legume-cereal intercropping emphasizing present field situation to 30 horticulture students from The Royal Veterinary and Agricultural University (KVL) and the Swedish University of Agricultural Sciences (SLU) requested by Professor Jacob Weiner.

Knudsen, M.T. and Jensen E. S. May 2003. Lecture and hands-on demonstration on field activities and research objective to 25 high school students from Falkonergården gymnasium, Frederiksberg, Copenhagen.

Jørnsgaard, B. 2003. Thai delegation, 7 reseacher and representant from the Thai embassy in Copenhagen. Organization of organic research in Denmark. Genesis given as an example. KVL, Højbakkegård, 15 september 2003.

Jørnsgaard, B. 6 June 2002 Darcof "Organic field walk" at KVL presenting GENESIS field trials.

Jørnsgaard, B. and E. S. Jensen Field visit at KVL. Delegation from Bangladesh, 22. June 2001

## Oral presentations

Hauggaard-Nielsen H 2003. Resultater fra forskning med dyrkning af blandingsafgrøder. Thematic day arranged by Danish National Organic Union (Økologisk Landsforening) inviting 20 participants (researchers, advisors and farmers) involved in specifying the final objectives and field protocols for the project "Produktion af kvalitetshvede ved samdyrkning med bælgssæd". Århus, Marts

Hauggaard-Nielsen H 2002 Dyrkning af blandingsafgrøder med bælgssæd. Thematic day Union (Økologisk Landsforening) arranged by Organic advisory services (Økologisk Rådgivning) for local farmers (50-70 participants) on Lyngby Landbrugsskole. Lyngby, December

Hauggaard-Nielsen H 2003. Hvorfor dyrke blandinger? Lecture in a brush-up course for farmers (25 participants) arranged by local advisory center (Agrogården, Ringe) by Advisor Richard de Visser to present and discuss present knowledge and practical experience for grain legume-cereal intercropping. Ringe, February

Hauggaard-Nielsen H 2003. Resultater fra forskning med dyrkning af blandingsafgrøder. Thematic day arranged by Danish National Organic Union (Økologisk Landsforening) inviting 20 participants (researchers, advisors and farmers) involved in specifying the final objectives and field protocols for the project "Produktion af kvalitetshvede ved samdyrkning med bælgssæd". Århus, Marts

Hauggaard-Nielsen H. 2002 Blandingsafgrøder og deres bidrag til bæredygtig planteproduktion. Thematic day arranged by The Danish National Organic Union (Økologisk Landsforening) with 15 participants (researchers, advisors and farmers) involved in production of protein and self-sufficiency in 2005. Odense, December

Hauggaard-Nielsen H. 2001 Dyrkning af blandingsafgrøder med bælgssæd. Thematic workshop at Snohøj IT Folkehøjskole titled " Proteinafgrøder i økologisk Jordbrug – dyrkning og fodring", November

Hauggaard-Nielsen H. 2002 Artsblandinger, udlægsår og eftervirkning. Talk for organics agricultural advisors arranged by the Danish Agricultural Advisory Centre and held at Reserach Station Jyndeved,

Danish Institute of Agricultural Sciences. The talk was followed up with some practical exercises using the GENESIS field trials, June

Hauggaard-Nielsen H. 2002 Blandingsafgrøder med korn og bælgssæd – erfaringer og nye udfordringer. Thematic field day at the Organic Research Farm Rugballegård, Danish Institute of Agricultural Sciences, August.

Hauggaard-Nielsen H. 2002 Blandsæd – bland afgrøderne og høst fordele. Talk to DLG-Økologi salesmen following a course in Organic Farming at FAF Odense, January.

Hauggaard-Nielsen H. 2002 Dyrkning af blandinger og høstteknologi. Talk to developer, technicians and salesmen at NewHolland, April

Hauggaard-Nielsen H. 2002 Joint meeting arranged by the KVL research group and DLG-Økologi to share experiences with grain legume cropping for invited farmers, agricultural advisors and process industries, May

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

\*Jensen, E.S. 2002 Intercropping – the application of ecological principles in organic plant production. Lecture in Course in Organic Farming, University of Western Australia, Perth.. 08.10.02. Department of Plant Biology, UWA, Oktober

Jensen, E.S. 2002 Research in organic farming and crop diversification. Seminar Jensen, E.S. 2002 Økologisk Jordbrug – Er det vejen til en bæredygtig fødevarerproduktion? Kandidat konference, KVL 2002.

Jensen, E.S. 2002 The application of ecological principle in organic crop production (Key-note). 3<sup>rd</sup> Australian organic Agriculture Symposium, Perth, Western Australia, 12 October 2002.

\*Jensen, E.S. 2002 The contributions of grain legumes to an environmental-friendly and sustainable European Agriculture. LINK dissemination, Strasbourg, September 2002.

\*Jensen, E.S. 2002. Økologisk Jordbrug – Er det vejen til en bæredygtig fødevarerproduktion? Seminar: Mad til verden uden forurening, Ingeniørforeningen, 3. 9. 2002.

\*Jensen, E.S. 2002. The role of grain legumes in an European environment friendly and sustainable agriculture. AEP Press Conference: "Pulses and human health", Madrid, 19 April 2002.

\*Jensen, E.S., Haugaard-Nielsen, H. and Jørnsgaard, B. 2002. Grain legumes – their role in European agriculture. Workshop: Integration of grain legumes in the maize-based production system in semi-arid Sub-Saharan Africa, 18 November, 2002, KVL.

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 planteavlsvudvikling og – forskning. Landbrugets Rådgivningscenter, Skejby, 19 april 2001. Oral presentation and abstract.

Jørnsgård B. 2002 Soter af lupin og sygdomme i lupin. Thematic day Union (Økologisk Landsforening) arranged by Organic advisory services (Økologisk Rådgivning) for local farmers (50-70 participants) on Lyngby Landbrugsskole. Lyngby, December

## F. Scientific education

The WP3 task 2 and some of the other WP3 intercropping aspects was performed in collaboration with PhD-student Mette Klindt Andersen, KVL.

Cand. agro Natalia Bellostas Muguerza finished her master project June 2001 titled "Early Interference Dynamics in Intercrops of Barley, Pea and Oilseed rape" in relation to WP3

Cand. agro Mikel Sarasua Larrañaga finished his master project June 2002 titled "Intercropping of Faba Bean with Pea, Barley and Oilseed rape: Grain Yield and Nitrogen Accumulation" in relation to WP3.

Cand. agro Marie Trydeman Knudsen did her master project. September 2002 "Samdyrkning af frøbælgplanter og vårbyg i økologiske dyrkningssystemer" in relation to WP3. .

Cand. Agro. B. B. Ghaley, finished his master project in June 2003 titled Pea-wheat intercropping and the effects of nitrogen fertilisation on productivity in relation to WP3.

Cand. agro Jacob Tranberg Nikolajsen finished his master project in July 2003 titled "Samdyrkning af ært og lupin med byg i økologisk jordbrug" in relation to WP3

Cand. agro Heidi Ravnberg finished her master project in August 2003 titled "Multi-species intercropping of grain legumes in organic agriculture" in relation to WP3.

Holdensen L. 2003. Fosforstress og dyrkning af bælgplanter i renbestand og samdyrket med byg – et forsøg med hestebønne ært og lupin. Bachelor project. August 2003, KVL in relation to WP2.

## **G. National and international cooperation**

### **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](mailto:Jorgen.Berntsen@agrsci.dk).

On an initiative from H. Hauggaard-Nielsen, an deputy head L. F. Møller, ([lfm@dlg.dk](mailto:lfm@dlg.dk)) DLG-Økologi a joint group for people with special interests in organic grain legume protein production is created including a total of 15 people; scientists, agricultural advisors, farmers, process industries and salesmen. The group will meet 3-4 times a year including 2 field days in the growth season.

A joint project meeting with the new DARCOF project GRANLEG, focusing on grain legume diseases, was established in June 2002. There will be additional separate project meetings with representatives from Grainleg, e.g. at the annual project meeting which took place in Jyndevad in 2003. Morten Priesholm from Økologien Hus and Michael Tersbøl from The National Advisory Centre are invited to the Genesis project meetings.

GENESIS WP3 has been involved in discussion and participation of two projects coordinated by The Danish National Organic Union (Økologisk Landsforening): "Proteinafgrøder" (<http://www.okologiens-hus.dk/proteiner/>) and "Produktion af kvalitetshvede ved samdyrkning med bælgæd".

### **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. ESJ, PA and SB has obtained EU support for a EU project on intercropping in organic agriculture in Europe from the last round in the 5 FP. The project started 1.1 2003 and partners are University of Kassel (D), ESA Angers (F), University Reggio Calabria (I) and University of Reading (UK) with the title: "Intercropping of grain legumes and cereals for European organic farming systems. Risø is the coordinator.

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.

In another EU project titled "New strategies to improve grain legumes for food and feed (Grain Legumes; 2004-2007)" knowledge from GENESIS has been included especially dealing with workpackage 2.1 "Lower input farming" coordinated by Erik Steen Jensen, Risø National Laboratory, Roskilde (funded by EU 6FP).

From a workshop held in Viterbo, Italy 10-12 April 2003 arranged by European Weed Research Society and the working Group 'Crop-Weed Interactions' good correlations has been made with European colleges focusing on the interaction between crop and weed plants (WP3 task 2 and 3).

## **H. Critical reflection on the project**

### **WP2. Task 1**

For determination of the effect of K-status on the N<sub>2</sub>-fixation it was decided to use the "natural abundance" method on Jyndevad. However, the results showed surprisingly that the natural enrichment of the <sup>15</sup>N pool in this specific coarse sandy soil was too low for the use of this method. Simple calculations of the N<sub>2</sub>-fixation will therefore be used instead.

### **WP3**

WP3 in close cooperation with WP1 decided to emphasize on lupines dealing with both ideotype studies and lupine-spring wheat competitive interactions partly due to a considerable interest among farmers and advisors and lack of knowledge in the literature. These activities are an extension of the original planned work. However, the quality of commercial rhizobial inoculants did not nodulate the lupines properly and the experimental sites were cancelled after the first harvest, 35 days after emergence. It was a surprise that commercial inoculants could be of such a poor quality but later investigation verified that there is no national regulation controlling the inoculants on the market. The lack of testing inoculants for inoculation ability was a mistake from our site. Collaboration is initiated between KVL and an UK inoculant company.

The level of natural <sup>15</sup>N abundance was surprisingly low at Jyndevad in 2001. It took a long time to verify the correctness of the analysis and therefore no further enrichment treatment was included in 2002. That was a failure leaving the N<sub>2</sub>-fixation estimates on the less sensitive and precise N-difference methodology. In 2003 extra <sup>15</sup>N

enrichment plots was implemented in the basic field trial at Jynde vad.

The close connection of WP3 activities to WP1 and WP4 objectives has been very fruitful. However, fewer initiatives towards WP2 and WP5 objectives picture the necessity to meet more often if the whole interdisciplinary research group want to have full benefits of each others scientific expertise and experiences. It is time consuming to meet more often but it may be worth it.

#### **WP5**

The present investigations on the nutritive quality of crops from organic farming have been interesting but relatively limited (due to a limited budget) and the results may be considered as only indicative. More systematic direct analyses and comparison on differences in nutritive quality between relevant crops from conventional and organic farming would give the opportunity to evaluate differences in the nutritive quality and potentials for improving the quality by organic farming

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## **8. Budget**

### **A. Account for any change in budgets**

We suggest that the project is prolonged for up to 3 months into 2004 with a new end date of 31 March 2004. The budgets are only presented for those WP tasks where project activities are planned in 2004: WP2.1 and WP2.2. and WP3.

#### **WP 2. Task 1. DJF.**

The project is prolonged two months into 2004. Funding is transferred from 2003 to 2004.

#### **WP 2. Task 2. KVL**

The field phosphor deficiency experiment was destroyed in year 2001 and 2002. In accordance with the DARCOF administration the field experiment was replaced by greenhouse pod experiments. The second of these experiments will not be finished before December 2003. In order to finalize the chemical analysis and the paper related to the experiment it would be necessary to transfer some of these activities to year 2004.

#### **WP 3. Risø**

We suggest that the project is prolonged three months into 2004 based on the transfer of funding from 2003 to 2004. Funding is available to employ a research assistant in this period. The prolongation is possible because tasks of WP3 have been co-managed with the new EU project on intercropping in organic farming. Thus we have been able to contribute resources from outside to Genesis.

WP3 established in 2003 a wheat-pea field trial (in addition to what was initially planned) on the Højbakkegård sandy loam soil to address the effects of interspecific competition on use of environmental plant growth resource and quality of wheat for bread making. A complete design was established with all combinations of wheat plant densities (0-600 plants m<sup>-2</sup>) and (0-200 pea plants m<sup>-2</sup>), in total 100 plots including 4 replicates and 4 successive harvests. The data will be used in NIR analyses of wheat according to several quality parameters for bread making. After a preliminary screening using the NIR methodology interesting samples will be analysed in more detail. A comparable fababean-wheat experiment conducted under the EU INTERCROP study may be included in a more general understanding and evaluation of grain legume-wheat intercropping used to achieve grains with bread making quality.

The same pea-wheat data will be used in an inverse hyperbolic non-linear linear regression models to quantify the competition effect among species grown in mixtures involving such complete density design to perform quantitative estimations of inter- and intra-specific competition in an integrated way over the whole density response surface to be used for more general competition interpretations.

## B. Budget for the whole project (1.000 DKK)

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

Year:	Consumption before 2003	Expected consumption 2003	2004	2005	Total
Man-months					
Scientific personnel					
Technical personnel					

Year:	Consumption before 2003	Expected consumption 2003	2004	2005	Total
Salaries	2.987	1.124,3	200,7		4.312
Scientific personnel					
Technical personnel					
Other operational costs	830	189,3	75,7		1.095
Equipment	5	1			6
Others (please specify)	44	17			61
Direct costs	3.866	1.311,6	276,4		5.474
Indirect costs (20% of direct costs)	774	261,6	60,4		1.095
Total	4.640	1.593,2	336,8		6.570

**Comments: See below for two workpackages (WP2.1, WP2.2 and WP3). We suggested that the project is prolonged up to three months into 2004 based on transfer of funding from 2003.**

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## 9. Signatures and stamps

Name	Institute	Date	Signature
Head of project			
Erik Steen Jensen	Risø National Laboratory	29.09.2003	

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## Appendix I. Detailed budget

### A. Budget for each participating institute (1.000 DKr)

Name of Institute: WP 2. Task 1 DJF (M. Askegaard)

Year:	Consumption before 2003	Expected consumption 2003	2004	2005	Total
Man-months					
Scientific personnel	5	2	2		9
Technical personnel	12	1			13

Year:	Consumption before 2003	Expected consumption 2003	2004	2005	Total
Salaries					
Scientific personnel	183	84,5	84,5		352
Technical personnel	199	8			207
Other operational costs	135	32			167
Equipment	5	1			6
Others (please specify)					
Extern analyses	38	4			42
Travels	6	3			9
Direct costs	566	132,5	84,5		783
Indirect costs (20% of direct costs)	113	22	22		157
Total	679	154,5	106,5		940

**Comments:** Two scientific months is transferred from 2003 to 2004

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## Institute: Department of Agricultural Sciences, KVL, WP 2.2 (B. Jørnsgård)

Year:	Consumption before 2003	Expected consumption 2003	2004	2005	Total
Man-months					
Scientific personnel	17.5	4	1		23
Technical personnel	8	1	0		9

Year:	Consumption before 2003	Expected consumption 2003	2004	2005	Total
Salaries					
Scientific personnel	637	175	30	-	842
Technical personnel	114	10		-	124
Other operational costs	162	34	5	-	201
Equipment					
Others (please specify)					
Direct costs	913	219	35		1167
Indirect costs (20% of direct costs)	183	44	7		233
Total	1096	263	42		1400

**Comments:**

The field phosphor deficiency experiment was destroyed in year 2001 and 2002. In accordance with the DARCOF administration the field experiment was replaced by greenhouse pod experiments. The second of these experiments will not be finished before December 2003. In order to finalize the chemical analysis and the paper related to the experiment it will be necessary to transfer some of these activities to year 2004.

Due to standards at the experimental station Højbakkegaard the cost for field and greenhouse experiments is characterized as other operational costs and not as technical personnel as foreseen in the original budget. The costs for technical personnel are consequently significantly reduced and other operational costs accordingly increased.

Name of Institute and department: WP3 Risø.

Year:	Consumption before 2003	Expected consumption 2003	2004	2005	Total
Man-months					
Scientific personnel	24	8	3		35
Technical personnel	9	2			11

Year:	Consumption before 2003	Expected consumption 2003	2004	2005	Total
Salaries	842,2	330,6	86,2		1287,8
Scientific personnel		283,1	86,2		
Technical personnel		47,5			
Other operational costs	320,0	150,3	70,7		512,2
Equipment					
Others (please specify)					
Direct costs	1.162,2	480,9	156,9		1800,0
Indirect costs (20% of direct costs)	232,4	96,2	31,4		360,0
Total	1.394,6	577,1	188,3		2.160,0

**Comments:**

**See above for suggested prolongation of project with three months.**

**B. Budget for each participating department (1.000 DKK)**

Name of Institute and department:

Year:	Consumption before 2003	Expected consumption 2003	2004	2005	Total
Man-months					
Scientific personnel					
Technical personnel					

Year:	Consumption before 2003	Expected consumption 2003	2004	2005	Total
Salaries					
Scientific personnel					
Technical personnel					
Other operational costs					
Equipment					
Others (please specify)					
Direct costs					
Indirect costs (20% of direct costs)					
Total					

**Comments:**

**C. Budget for co-financing from each participating institute (1.000 DKK)**

Name of Institute:

Year:	Consumption before 2003	Expected consumption 2003	2004	2005	Total
Man-months					
Scientific personnel					
Technical personnel					

Year:	Consumption before 2003	Expected consumption 2003	2004	2005	Total
Salaries					
Scientific personnel					
Technical personnel					
Other operational costs					
Equipment					
Others (please specify)					
Direct costs					
Indirect costs (20% of direct costs)					
Total					

**Comments:**

## Fyldigt dansk sammendrag af indsatsen i forskningsprojektet

### Titel

II-5. Frøbælgplanter og korn – nye dyrkningsmetoder for større proteinforsyning i økologisk jordbrug (Genesis)

### Projektleder

Forskningsprofessor, dr.agro. Erik Steen Jensen

Afd. for Planteforskning

Forskningscenter Risø

4000 Roskilde

Tlf: 46774108, Fax: 46774260, E-mail: [erik.s.jensen@risoe.dk](mailto:erik.s.jensen@risoe.dk)

### Baggrund

Der er et stort behov for at forøge produktionen af protein og kornafgrøder i det økologiske jordbrug i Danmark for at kunne dække det stigende behov for fodermidler til svin og fjerkræ. Desuden skal alle fodermidler være økologisk producerede, dvs. og så GMO-fri, fra 2005 i EU. Frøbælgplanter, fx ært, hestebønne og lupin, og korn komplementerer hinanden i foderblandinger og de nævnte frøbælgplanter er de bedst egnede proteinafgrøder til dyrkning under danske klimaforhold. Udover at være værdifulde protein- og energikilder i foderblandinger (og i humane diæter med et lavt kød indhold), bidrager frøbælgplanterne til det økologiske jordbrugssystem med kvælstof via deres evne til biologisk at fikse luftens N<sub>2</sub> i symbiose med rodknoldbakterier og deres forfrugtsværdi, især som fodsyge-sanerede afgrøder i dyrkningssystemer med relativt meget korn. Frøbælgplanter har imidlertid ry for at være dyrkningsusikre afgrøder, pga. tørkefølsomhed og lejesædstilbøjelighed for nogle arter, sen modning for andre og en variabel kvalitet af frøene.

### Formål og perspektiver

Hovedformålet med dette projekt er at vurdere potentialet for dyrkning af flere frøbælgplanter i økologiske dyrkningssystemer for øget proteinproduktion til anvendelse i fodringen af svin og fjerkræ. I projektet vil vi identificere faktorer som begrænser produktionen af frøbælgplanter og korn via undersøgelser som inddrager effekten af jordtype/klima, kalium og fosfortilgængelighed, plantesygdomme og ukrudt. Følgende nye dyrkningsmetoder vil blive undersøgt: samdyrkning af frøbælgplanter og korn og betydningen af plantepopulationstæthed i relation til ukrudtsregulering hos frøbælgplanter. I projektet vil frøbælgplantearter og genotyper blive vurderet i relation til deres egnethed i økologiske systemer, især i relation til samdyrkning og ukrudtsregulering. Vi vil desuden bestemme kvælstoffiksering, afgrøde N balancer, tilgængeligt N om efteråret og for den efterfølgende afgrøde, samt kvaliteten af frøbælgplantefrø i relation til fodring af svin og fjerkræ.

Formålet med projektet er også at bidrage med grundlagsskabende ny viden om fundamentale processer og sammenhænge i økologiske dyrkningssystemer. Det drejer sig om sammenhængen mellem frøbælgplanters fænologi og konkurrenceevne af afgrøden overfor ukrudt og egnethed for samdyrkning, variabilitet i afgrødetolerance overfor lave niveauer af fosfor og/eller kalium hos frøbælgplanter, multipel ressourceudnyttelse i blandingsafgrøde/ukrudtssamfundet, vurdering af mulige mekanismer for ukrudtkontrol i blandingsafgrøder, den mulige betydning af interspecifik konkurrence i samdyrkede afgrøder, som et redskab til at kontrollere kvaliteten af kornpro-

dukter, etablering og udvikling af sygdomme i blandingsafgrøder, betydning af næringsstofstatus for plantesundhed og næringsværdien af frøbælgplanter og korn produceret i økologiske dyrkningssystemer.

### **Kort beskrivelse**

Projektet er opdelt i fem delprojekter, de såkaldte workpackages (WP).

#### **WP1. Frøbælgplanter til renbestand og samdyrkning i økologiske jordbrugs-systemer**

Delmålene er:

- At bestemme frø og halmudbytte, N<sub>2</sub> fiksering og kvalitet af ærte-, hestebønne- og blå lupin typer dyrket i økologiske dyrkningssystemer på to jordtyper i tre år,
- At bestemme strategier for frøbælgplantevalg og placering i sædskiftet
- At evaluere tilgængelige frøbælgplantesorter og -liniers egnethed for dyrkning i renbestand og til samdyrkning med vårbyg, hvede, og triticale, og at
- At vurdere ideotyper af blå lupin med forskellige vækstrytmer, højde og forgreningsstruktur for deres egnethed for samdyrkning og evne til at undertrykke ukrudt.

#### **WP2. Produktion af frøbælgplanter og korn ved lave fosfor og/eller kalium-niveauer**

Delmålene er:

- At bestemme effekten af lav K-status på produktion af protein i frøbælgplanter og korn på en grovsandet jord,
- At forbedre beslutningsgrundlaget for K-gødskning af disse afgrøder,
- At bestemme forskellige frøbælgplanters (og korns) tolerance overfor lavt P niveau i jorden, og
- At bestemme P-optag, udbytte og frøkvalitet ved lavt P-niveau hos forskellige frøbælgplanteafgrøder

#### **WP3. Samdyrkning af frøbælgplanter og korn: ressourceudnyttelse og ukrudtsregulering**

Delmålene er:

- At bestemme effekten af samdyrkning af ært, hestebønne og blå lupin typer med korn på udbytte, N udnyttelse, udbyttestabilitet (3 år), tilgængelig jord N om efteråret og kvalitet af frøbælgplante- og kornfrø sammenlignet med de respektive renbestande på to jordtyper, og
- At bestemme konkurrence og multipel ressourceudnyttelse i blandingsafgrøde/ukrudt samfundet af ært-byg blandingsafgrøder afhængigt af samdyrkningsdesign og plantepopulationstæthed for at vurdere potentialet for ukrudtsregulering via samdyrkning og/eller ændret plantetæthed i frøbælgplante renbestande.

#### **WP4. Plantesundhed i frøbælgplanter og korn**

Delmålene er:

- At bestemme hvorledes samdyrkningssystemer af frøbælgplanter og korn indvirker på etablering og udvikling af relevante plantesygdomme, og
- At opnå en bedre forståelse af hvorledes ændringer i plantekvalitet og fysiologi, pga. af forskellig tilgængelighed af næringsstoffer (N, K og Si) i jorde med lavt K indhold og samdyrkning påvirker sygdomsresistensmekanismer.

## WP5. Kvalitetsaspekter

Formålet er gennemføre en kemisk og ernæringsmæssig karakterisering af udvalgte sorter af ært, hestebønne, og blå lupin dyrket som renbestande eller i blanding med korn, på forskellige jordtyper og ved forskellige næringsstofstatus i jorden. Følgende parametre vil blive undersøgt:

- Kemisk sammensætning – protein, fedt, kulhydrater og aminosyrer,
- Fordøjelighed af næringsstoffraktioner baseret på *in vitro* analyser, og
- Sekundære faktorer som har indflydelse på næringsværdien baseret på analyser af ANFs og en biologisk model ved anvendelse af en standardiseret rottebioassay.

## Aktiviteter 2003

### WP1: Frøbælgplanter til renbestand og samdyrkning i økologiske jordbrugssystemer

Der er gennemført forsøg på Højbakkegård og Jyndevad Forsøgsstation vedr. udbyttestabilitet hos frøbælgplanter dyrket i renbestand og i blandinger med vårbyg (se WP3). Forsøgene har omhandlet lupin, 2 ærtetyper og hestebønne samt to vårbyg sorter med normalt og højt indhold af lysin. Forsøgene er nu gennemført i 3 år og der vil i slutningen af 2003 været et komplet datasæt vedr. variation i udbytte, kvalitet, kvælstoffiksering, uorganisk N udnyttelse og eftervirkning på de to lokaliteter.

Hovedparten af aktiviteterne under denne WP er gennemført i 2000-2002.

### WP2. Produktion af frøbælgplanter og korn ved lave fosfor og/eller kaliumniveauer

#### Delprojekt 1: Kalium

I to forsøg (2001 og 2002) er fire forskellige afgrøder dyrket ved to kaliumniveauer for at belyse betydningen af jordens evne til at forsyne planterne med kalium på udbytte, kvælstoffiksering, kalium optag på en sandjord (Jyndevad). Der er efterfølgende dyrket vårbyg for at måle eftervirkning af de forskellige afgrøder og K-gødskning. I 2003 er det sidste eftervirkningsforsøg gennemført tilfredsstillende, men resultaterne er ikke endeligt analyseret.

De foreløbige resultater har bl.a. vist 1) Udbytte i hestebønner og ært steg med tilførsel af K i modsætning til lupin hvor udbytte var upåvirkede af K behandlingerne. 2) en væsentlig del af afgrødernes K optagelse, der kunne overstige 200 kg ha<sup>-1</sup>, er sandsynligvis kommet fra "ikke-ombyttelige" K-reserver og/eller fra jordlag dybere end 20 cm. 3) målinger af jord pH viste ingen fald gennem vækstsæsonen som det var forventet især under lupin. 4) det antages normalt at afgrødens indhold af K topper ved blomstring, men dette var ikke tilfældet i forsøget hvor K-optagelsen steg over en betydelig længere periode. 5) mangelsymptomerne for K mangel i ært viste sig først sent da nogle af topskuddene visnede og i hestebønne var det på afgrødehøjden at forskellen slog igennem. Målinger af K indvirkning på N<sub>2</sub>-fiksering måtte opgives da den anvendte metode "natural abundance" viste sig ikke at kunne anvendes på den grovsandede jord.

### Delprojekt 2: Fosfor

Efter aftale med FØJOs ledelse er der gennemført pottforsøg som kompensati- on for de markforsøg som blev ødelagt af fugle (2001 og 2002). Det ene af disse pottforsøg afsluttes først i december 2003. Det første forsøg med dyrkning af forskellige frøbælgplanter og vårbyg på en jord med en meget lav fosfor tilgæn- gelighed uden og med tilførsel af P viste at både ært og hestebønne respondere kraftigt på P tilførsel, hvorimod byg og lupin ikke viste symptomer på P begræn- set vækst uden tilførsel af P. I byg kan den manglende effekt af P skyldes at planterne var N begrænsende. Ved samdyrkning af byg og frøbælgplanter opnå- edes de største udbytte fordele ved samdyrkning ved det laveste P niveau, og fordelene var større for blandinger af ært-byg og hestebønne-byg end for lupin- byg.

## **WP3. Samdyrkning af frøbælgplanter og korn: ressourceudnyttelse og ukrudtsregulering**

### Delprojekt 1:

I 2003 gennemførtes tredje års forsøg med frøbælgplanter og korn i renbestand og blanding på Højbakkegård og Jyndevad Forsøgsstation. Forsøgene forløb til- fredsstillende og i slutningen af året vil det samlede treårige datasæt kunne be- nyttes til at vurdere udbyttestabilitet mm af de forskellige arter på de to lokaliteter. Der vil desuden være data vedr. eftervirkning i den følgende afgrøde af de for- skellige arter.

### Delprojekt 2:

I en række forsøg er der målt hvorledes samdyrkede afgrøder udnytter andre plantevækstfaktorer end N, fx lys, vand, fosfor og kalium. Måling af lys absorbtio- nen i en afgrøde er foretaget ved gradvist at fjerne afgrødekomponenterne: ært, byg og til sidst ukrudt. En foreløbige opgørelse af resultaterne viser bl.a. at byg reducerer andelen af den samlede indstråling som absorberes i samdyrket ært. Målinger af afgrøderne vandoptag har desværre begrænset værdi fordi jorden i de pågældende forsøg var velforsynet med vand i det meste af vækstsæsonen.

### Delprojekt 3

To forsøg gennemførtes med henblik på at belyse effekten af samdyrkning på ukrudtsudviklingen sammenlignet med renbestand af byg og frøbælgplanter. Det ene forsøg viste at der negativ korrelation mellem ukrudtets tidlige udvikling og afgrødens optag af uorganisk fra de øverste jordlag og afgrødens bladareal. I et andet forsøg var formålet at belyse effekten af at øge antal af arter i en blan- dingsafgrøde på udbytte, ressource udnyttelse og konkurrence overfor ukrudt. Der benyttedes op til tre frøbælgplantearter samtidigt i blanding med byg. Resul- taterne viste at det var mere vigtigt hvilke arter som indgik end hvor mange, samt det at tilføje yderligere en art til en blanding kan medføre betydelige ændringer i konkurrence forholdene mellem de "allerede tilstedeværende" arter i blanding.

## **WP4. Plantesundhed i frøbælgplanter og korn**

### Delprojekt 1:

I 2003 er forsøg i WP3.1 blevet studeret mht. til effekten af samdyrkning på plan- tesundheden. Desuden er der for andre projektmidler foretaget en udvidelse af

forsøgene, således at det har været mulighed at studere afgrøderne ved forskellige N-niveauer. De foreløbige resultater er i overensstemmelse med tidligere års resultater, nemlig at samdyrkning reducerer forekomsten af en række sygdomme og at størrelse af reduktionen bl.a. afhænger af sygdommens spredningsmekanisme, højden af afgrøden og kvælstofniveauet. Desto højere N-niveau desto mindre er effekten af samdyrkning for sygdomsreduktionen.

Delprojekt 2:

Drivhus forsøg er gennemført i 2003 mht. at belyse effekten af planters N, P og K forsyning på bygplanters resistens overfor meldug. Både N, P og K påvirkede meldug i byg med de kraftigste effekter af N og K. Der er vist vekselvirkning mellem N og K mht. planternes sundhedstilstand.

#### **WP5. Kvalitetsaspekter**

En række kvalitets analyser er udført på prøver fra forsøgene i 2001 og 2002. Forsøgene viser at samdyrkning øger proteinindholdet i byg i modsætning til N gødsning med mindre N mængder. Stivelse og råfedtindholdet var derimod mindre i samdyrket byg. Analysearbejde med bl.a. fordøjelighedsforsøg er ikke afsluttet.

Det anmodes om, at projektets afslutning udskydes til 31. marts 2004, da der på tre af WP er midler som kan overføres for aktiviteter i 2004. Mulighederne for videreførelse motiveres bl.a. i at det har været mulig at samordne forsøgsaktiviteter med et nyt EU projekt, hvorved det bliver mulig at se på fx bagekvalitet af samdyrket hvede i større omfang end oprindeligt planlagt.