



## Midterm Status Report 2002 and Application for Continuation in 2003

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The Directorate for Food, Fisheries and Agro Business  
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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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## 6. Project period (month, year)

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

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

### 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, faba bean 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 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> , JLC, 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	2160	Feb. 2001	Dec. 2003	9-13
4	Plant health in relation to intercropping and nutrient uptake	<u>ML</u> , MM	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 extend differences exist between grain legume species and varieties in recovering and utilise 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**

The two years field experiment was finished in year 2001. The experiment was carried out on a sandy loam. Twenty-eight pea, 12 faba beans, 8 lupin, 11 spring barley, 10 spring triticale and 8 spring wheat cultivars were tested in sole and inter cropping, at respectively normal sowing density and at 50% of normal density in the mixed plots. The grain legumes were tested in intercrop with one standard spring barley variety Otira and the cereals were tested in intercrop with one standard pea variety Agadir.

Plant development including the time of key development stages and plant heights in sole 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. In year 2000 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 standing ability. Traditional branched lupins and faba beans outgrew and ripened much later than the intercropped cereals. Weed infestations were comparable in the mixtures of grain legumes with cereals compared to the cereal sole crop but decreased several times compared to the legume sole crops. In year 2001 all plots were harvested ultimo august despite they were not sown before the late April. The significant differences between species observed in year 2000 in development and ripening time was remarkable reduced in year 2001 due to a warm dry august which forced even the faba bean to ripen. It was also noted in this year that the intercropped legumes ripened earlier than the sole cropped, probably due to competition for water.

Variety differences in development and ripening were in general insignificant compared to differences between species except for the differences between the earliest and latest triticale and for the non-branching and wild branching lupins. Cereal responded significantly different to intercropping with the different grain legumes species. Peas competed much more strongly with the cereals than the lupin, and the cereal yield in intercrops with peas was reduced by nearly 50% compared to the cereal yield in the intercrops with lupins. The protein content increased dramatically by app.1/3 in wheat, barley and triticale, when intercropped with fababean and peas compared to sole crop cereal, whereas the response to lupins is significantly lower app. 10% increase.

The preliminary conclusion is that with respect to acceptable synchronous development and ripening barley, spring wheat and triticale can be intercropped with all tested pea varieties and the earliest reduced branching types of lupins. The highest grain yield was found the pea-barley intercrops, whereas the highest protein yield was observed in the sole lupin crops. The yield and protein increase which was found in the intercrops of cereals and pea/ fababean were not found in the mixtures of lupin and barley, however the reduction in weed infestations were the same for all legume species when intercropping with cereals (Table 1).

**Table 1.** Grain and protein yield, protein concentration and weed infestation of sole crops and mixtures of cereals and grain legumes in the variety experiment 2001 at Højbkkegaard.

Cereal species	Legume species	grain yield			grain protein		Weed g/m <sup>2</sup>	
		total g/m <sup>2</sup>	cereal g/m <sup>2</sup>	legume g/m <sup>2</sup>	total g/m <sup>2</sup>	cereal %		legume %
barley	-	384	384		35	9.1	16	
wheat	-	322	322		37	11.5	12	
triticale	-	240	240		33	13.9	15	
-	pea	342		342	72		21.2	42
-	fababean	353		353	100		38.3	175
-	lupin	389		390	121		31.1	75
wheat	pea	411	141	270	77	15.6	20.8	21
triticale	pea	345	129	216	62	16.5	20.5	22
barley	pea	433	140	304	76	13.6	20.8	18
barley	fababean	411	212	199	80	11.7	28.1	23
barley	lupin	394	245	149	72	8.8	34.0	19
Isd.0.05		88	54	107	19	1.7	1.7	30

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 in year 2001 and 2002 (a similar experiment will be carried out in 2003). One genotype of faba 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 as sole crops 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). 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 ripening one m<sup>2</sup> 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 15N natural abundance method. Further information on these experiments are reported in WP3 task 1.

Task 3. Ideotypes for intercropping and weed suppression ability

Narrow leafed lupin is used as a model crop. Twelve and 15 genotypes in the first and second year respectively, varying earliness of stem elongation and branching structure, were grown at 100 plants per m<sup>2</sup> in intercrops with one barley variety sown at 50 plants per m<sup>2</sup>. The height development was followed during the growing season and at ripening samples were taken for determinations of yield components of the lupines and the effect of the different lupin growth forms on the barley yield components and the natural occurring weeds.

Significant differences in yield components in barley were observed when grown in intercrops with the different lupin types. The total biomass of barley was not affected significantly, however, there was a tendency for higher barley biomass in intercrops with the lupins with the most reduced branching. The grain yield of barley was highly significantly affected by the lupin canopy structure and the grain yield was 50% lower when barley was grown in intercrops with the most branching type compared to the barley yield in intercrops with the most restricted lupin, due to a reduction in barley seed weight by 20% and in total grain number by 30% (Table 2). Both the highest total grain yield and protein grain yield are obtained for the same lupin genotype, which is a type without branching, early ripening, with a height comparable to barley. Despite having only a minor effect on the barley yield, this type has itself the second highest grain yield of all lupin types and a high harvest index.

The highest lupin grain yield is obtained in a wild branching type; however, this type results in the lowest barley yield of all types. The total grain yield and total protein yield is consequently significantly inferior to the best combination. Furthermore this branching structure cause late ripening of the lupin and can under practical farming conditions results in grain shattering in barley, which ripens significantly before the lupins. On average the biomass of the natural weed population was only 2% of the total biomass of 10.5 ton per ha. Lupin and barley made up approximately 50% each. The weed biomass was not affected by the type of lupin as expected. This is probably due to the low weed infestation, and the dominating effect of cereals on weed over the effect of grain legumes on the weed when grown in intercrops, which is described in task 1 in this work package.

The preliminary conclusions are that the very restricted branching lupin types provides the best component for intercropping with cereals as it gives the highest total yield, is not suppressing the cereals, provides comparable growth and development cycle to the cereal. The restricted lupins less competitive ability appear not to be important in intercrops with cereals for the weed control because the cereals control the weed.

**Table 2.** Barley performance in intercrop with different lupin-ideotypes, varying in branching structure, initial growth and height.

Lupin genotype	Lupin branching 1=none 9=many	Lupin quickly growth 1=slow 9=quickly	Lupin height 1=small 9=tall	Total grain yield g/m <sup>2</sup>	Barley grain yield g/m <sup>2</sup>	Lupin grain yield g/m <sup>2</sup>	Barley seed weight mg	Weed biomass g/m <sup>2</sup>
LAE1	1	5	3	533	282	252	48	27
ROSET_E_	1	1	2	488	307	181	47	20
LAE32-2	1	7	3	488	303	185	48	20
LAE6	1	3	3	487	278	208	47	24
LAE2-2	1	7	5	476	350	126	49	16
LAP12-1	3	3	5	515	320	195	50	19
LAV8-4	2	5	7	446	263	182	40	17
LAF8-8FR	4	7	5	510	296	214	48	20
LAP17-1	4	5	7	377	220	156	43	22
LAG24	5	5	7	508	288	220	47	24
LAG28	7	5	7	399	199	200	44	18
LAW12-WS	9	5	9	427	173	254	39	18
lsd.0.05				75	88	45	3	18

## WP2. Performance of grain legumes and cereals at low K and P levels

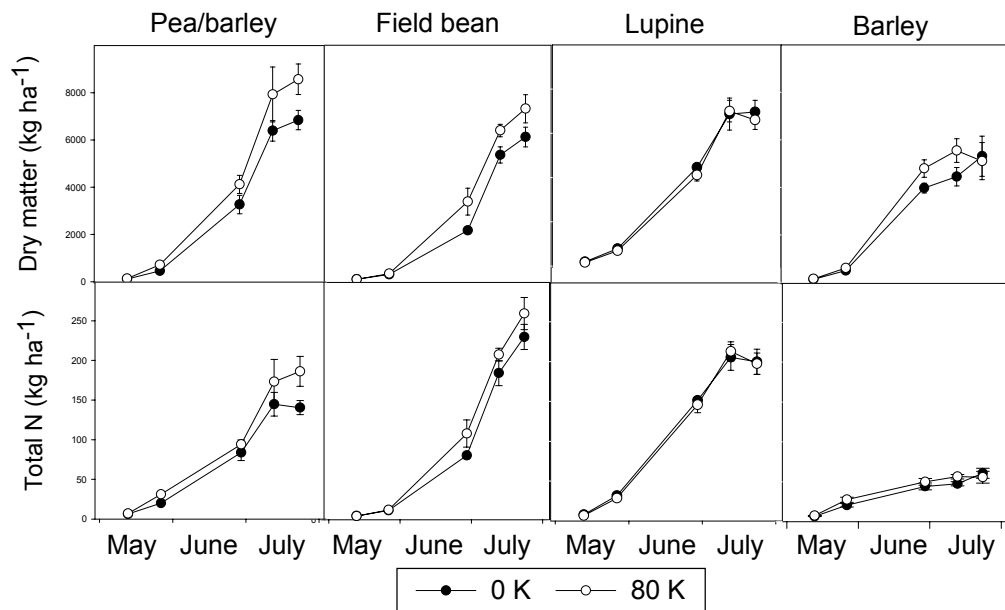
### Task 1. Determination of the effect of low K-status on the production of protein in cereal and grain legume crops on a coarse sandy soil.

Four different sole crops/intercrop (barley, pea/barley, field bean and lupine) are tested at two different levels of K (0K and 80 kg K ha<sup>-1</sup>) in four replicates. 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 growth season 2002 passed without major problems despite a severe attack of botrytis in the lupines, which, like 2001, stopped the growth in the middle of the seed filling. The yields for 2002 have not been estimated. Table 1 shows the yield and N contents of the 2001 harvest and Figure 1 shows the growth rates and N-uptake/production rates in the four tested crops.

**Table 3.** Dry matter yield (DM) and N content of grain and seed, 2001

Crop	DM (t ha <sup>-1</sup> )		%N in DM		N (kg ha <sup>-1</sup> )	
	0K	80K	0K	80K	0K	80K
Barley	2 <sup>a</sup>	2.4 <sup>a</sup>	1.5 <sup>a</sup>	1.5 <sup>a</sup>	30 <sup>a</sup>	35 <sup>a</sup>
Pea/barley	2.4 <sup>a</sup>	3.4 <sup>b</sup>			86 <sup>b</sup>	114 <sup>a</sup>
Barley	1.0 <sup>a</sup>	1.2 <sup>a</sup>	2.4 <sup>a</sup>	2.1 <sup>a</sup>	23 <sup>a</sup>	25 <sup>a</sup>
Pea	1.4 <sup>b</sup>	2.2 <sup>a</sup>	4.6 <sup>a</sup>	4.0 <sup>b</sup>	63 <sup>a</sup>	89 <sup>a</sup>
% pea	58	65				
Lupine	1.2 <sup>a</sup>	1.2 <sup>a</sup>	5.9 <sup>a</sup>	6.1 <sup>a</sup>	72 <sup>a</sup>	70 <sup>a</sup>
Faba beans	2.6 <sup>b</sup>	3.6 <sup>a</sup>	5.8 <sup>a</sup>	5.6 <sup>a</sup>	149 <sup>b</sup>	200 <sup>a</sup>



**Figure 1.** Dry matter production and N content as affected by application of K, 2001

The following preliminary conclusions can be drawn from the 2001 results:

- Yields in faba bean and the pea component in the pea/barley intercrop increased with about 40% with K application
- Despite a very low level of exchangeable K, 2-3 mg K 100 g soil<sup>-1</sup>, the yields of barley and 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 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 on 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 lowest level of soil phosphorus is 10-15 ppm (bi-carbonate extraction) in this field. At each of the main plots the seven combinations consisting of the four sole crop and the three mixture combinations of barley intercropped with pea, faba bean and lupin, respectively. Despite the installation of three bird scare alarms the trial was severely damaged by birds and hares in a systematic way leaving the plots nearest the alarms relatively undamaged. The experiment was 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 fababeans over lupins and peas. The trial was replanted in 2002 in the same design. To protect it from destruction by birds it was covered by elastic nets, which were lifted 20 cm above ground by plastic sticks. Despite these precautions birds in large numbers were able to press the net to the ground and only legume plants, which stayed near the plastic stick, were not eaten.

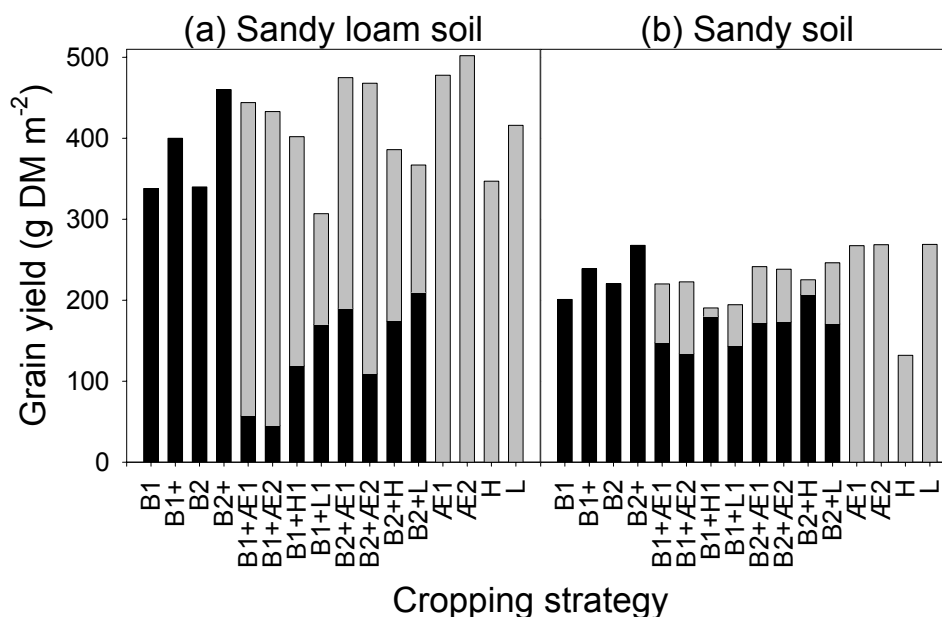
It is concluded that within the given budget in this project it is not possible to grow grain legumes in this long term experimental unit concerning long time effect of increasing application of N, P and K, because it covers a field of more than 300 m length and because the area is under heavy bird damage pressure. Furthermore the area has a small hill in the middle and will require minimum two persons to keep birds away or expensive netting.

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

#### **Task1. Intercropping of grain legumes and cereals on two soil types during three years.**

The objectives are to determine the effect of grain legume-cereal intercropping on the yield, N use, yield stability (3 years), residual soil N and the quality of grain legume and cereal seeds as compared to sole crops (SC) on two soil types: A sandy loam soil at Højbakkegård and a sandy soil at Jyndevad Research Station. Further description of the experiment see WP1 task 2.

Differences in soil and climatic conditions regulated the grain legume-barley intercrop (IC) composition with the grain legumes as dominating species on the sandy loam soil and vice versa on the sandy soil. Sole crop grain yields were about the double on the sandy loam compared to the sandy soil for both grain legumes and the cereal (Figure 2). Barley yields in intercrop were similar on both sites, whereas the intercropped grain legumes on the sandy soil yielded only 20% of the yield at the sandy loam. Combined grain yields in IC compared to SC showed the same level within the two locations, but obviously with considerable different grain quality composition.

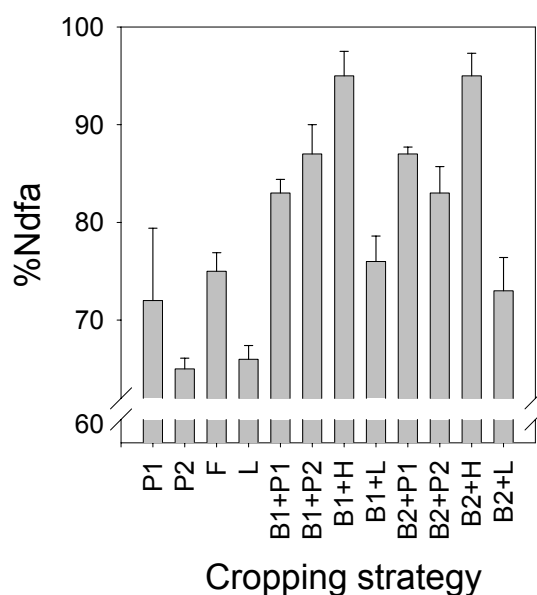


**Figure 2.** Grain dry matter yield of barley cultivars (B1 and B2) pea cultivars (P1 and P2), faba bean (F) and lupin (L) grown as sole crops and 50%:50% mixed dual cereal-grain legume intercrops in replacement design on two soil types in 2001.

Especially on the sandy soil, fababean were strongly suffering from late sowing and a rather dry and warm first month of growth. Late sowing intensifies drought risk on this soil with low nutrient status and low water-holding capacity. Such growth conditions are the main reasons to the yield variations comparing fababean performance on the two soil types contrary to e.g. lupin with its deeper root system. Lupin showed the ability to obtain similar yields independent of cropping strategy, soil and climatic conditions. Sole cropped lupin had the highest grain protein yields of all crops.

Fababean-barley intercrops use environmental resources for grain production 15% more efficiently than sole crops, which were not observed for neither pea-barley, nor lupin-barley intercrops. The environmental sources for plant growth based on grain N yields indicated that N sources were used up to 30% more efficiently in all intercrops compared to sole crops, except from lupin-barley mixtures on the sandy loam. Intercropped lupin is more competitive than pea and fababean reducing the intercropping advantages caused by sharing of resources among species. Lupin showed a superior ability to both fix atmospheric  $N_2$  and take up soil N. On the sandy loam sole cropped lupin took up significantly more soil N than the lupin-barley intercrop.

In cereal-grain legume intercropping there is an efficient exploitation of soil inorganic N sources by the cereal, while at the same time fixed N from the grain legume enters the plant-soil-system. On the sandy loam site sole cropped pea and fababean results indicated that the  $N_2$  fixation constituted only 65% of shoot N derived from fixation compared to 85% when intercropped. This was not observed to the same degree in lupins possibly due to its competitive ability for soil N reducing the proportion of N derived from fixation (Figure 3). The first year of the three-year study indicate that intercrops of pea-barley and fababean-barley offer an opportunity to improve the use of N resources. Lupin intercrops did not show the same advantage over lupin sole cropping.



**Figure 3.** Effect of cropping strategy on the proportion of aboveground N accumulation derived from fixation (%Ndfa) in pea (P1 and P2), faba bean (F) and lupin (L) when sole cropped and intercropped with barley (B1 and B2) on a sandy loam soil in 2001 - based on shoot N and estimated by  $^{15}\text{N}$  natural abundance technique.

The two barley cultivars showed different competitive ability towards the intercropped grain legumes whereas no effect of pea cultivar was determined. This is not in agreement with published work from the KVL research group showing that the choice of pea cultivar in the intercrop influenced the intercrop performance to a larger degree than the choice of barley cultivar. Together with the WP1 genotype study and the 2-yr continuants of this experiments it will be possible to evaluate the possibilities of changing intercrop performances by choice of cultivars.

A significant increase in barley grain N concentration was observed when intercropped with pea or fababean compared to sole cropped barley (Figure 3). Grain legume-cereal intercropping shows potentials for managing and possibly improving cereal grain quality. Especially the increase in protein concentration of the barley cultivar bred for high lysine content seems promising because such increase is known not to be negatively correlated with protein quality.

Residue quality differences often results in a lower preceding crop effect after cereals compared to after grain legumes. However, it was not possible to measure any significant differences in either the undersown ryegrass or subsequent spring oat. On the sandy soil the poor grain legume yields and potential for N leaching in a rather wet autumn may be the reason for the lack of differences in oat N uptake. On the sandy loam soil lack of precrop effects was surprising. The weak establishment of the undersown ryegrass in combination with an extraordinary wet September may have blurred the treatment effects on this site.

The preliminary conclusions are that present results only provide a rough guide as to what combinations of crops might be most viable. However, it is expected that the coming two years results will gain substantial findings to obtain general conclusions about intercrop competitive aspects and intercrop performance when comparing the grain legumes species at the two very different locations.

#### **Task 2a Use of multiple resources by intercrop/weed and monocrop/weed communities**

A semi-field pot experiment was conducted in 2001 to study the resource use, growth and competition dynamics of pea, barley and oil seed rape grown as sole crops and as components of dual and tri-component intercrops in a proportional replacement design. This preliminary evaluation of the experiment is based on biomass data collected at three harvests over the growing season as well as grain yields.

Barley and pea were both sown as sole crops at what was denoted as full and half density. For both crops total final yields were only slightly lowered by a 50% reduction of crop density. The barley grain yield was affected by cropping strategy. Despite equivalent barley density, the grain yield of barley grown in intercrop with pea was significantly lower than in the half density sole crop. A similar pattern was not observed for pea. Although the initial density of both barley and pea plants differed between the dual and tri-component intercrops, these intercrops yielded similar amounts of both pea and barley grain, respectively. Including sequential harvests in the experimental design has allowed us to study the changes in competitive interactions, between the included crop species, over time. Using the competitive ratio index (CR), an index that expresses the competitive ability of one component of an intercrop relative to the other, it is apparent that the barley component of both the pea-barley and pea-barley-rape intercrops was competitively superior to pea, the CR of barley relative to pea averaging at 1.2. However, in the last third of the growing season the situation switched and the pea component was found to exert the strongest competitive pressure. White mustard was incorporated as a model weed. Throughout the growing season it was apparent that barley was much more competitive towards the weed than pea, placing most competitive pressure on the weed population when grown as a sole crop at full density. However the pressure exerted by both the dual pea-barley and triple pea-barley-rape intercrops as well as the sole crop barley grown at half density well exceeded that of sole cropped pea.

Although preliminary, for pea this study does show that a decrease in density, from sole crop to intercrop and from sole crop at full to half density, lead to a great degree of individual plant adjustment, the per plant biomass accumulation increasing markedly. A similar adjustment was seen when the density of sole cropped barley was halved but not for the barley component of either intercrop. Land equivalent ratios, calculated on the basis of total biomass at the final harvest, indicate that available growth resources were more efficiently employed in the intercrops than in the comparable sole crops. Finally the inclusion of sequential measures of yield appears to give valuable insight into the competitive dynamics of an intercrop.

#### **Task 2b Effects of intercrop design and plant density on weed growth**

To evaluate the optimum combination and design of intercropped pea and barley to determine yield and quality aspects compared to sole cropping as well as competitive ability towards weeds a field trial was conducted at KVL in 2001. The crop species were grown at 50, 100 and 200% of the recommended density at two intercrop relative frequencies (1/3 pea+2/3 barley and 2/3 pea + 1/3 barley) including replacement versus additive design. Analysis of N is still in progress wherefore this preliminary evaluation of the experiment is based on biomass and grain yield data collected at three harvests over the growing season.

The competitive interference during early growth stages is often the determining factor for the use of environmental resources in intercrops and thus for the final achievement of intercrop yield advantages. From tillering to the elongation growth stages total crop aboveground dry matter yield increased significantly as the density was raised independent of species, intercrop frequency and design. However, at the final harvest these differences were balanced out. A general low weed pressure on this site together with exceptionally fast germinating and tillering crops due late sowing and warm temperature during early growth may have hidden the effect of differential competition from crops on final yield results.

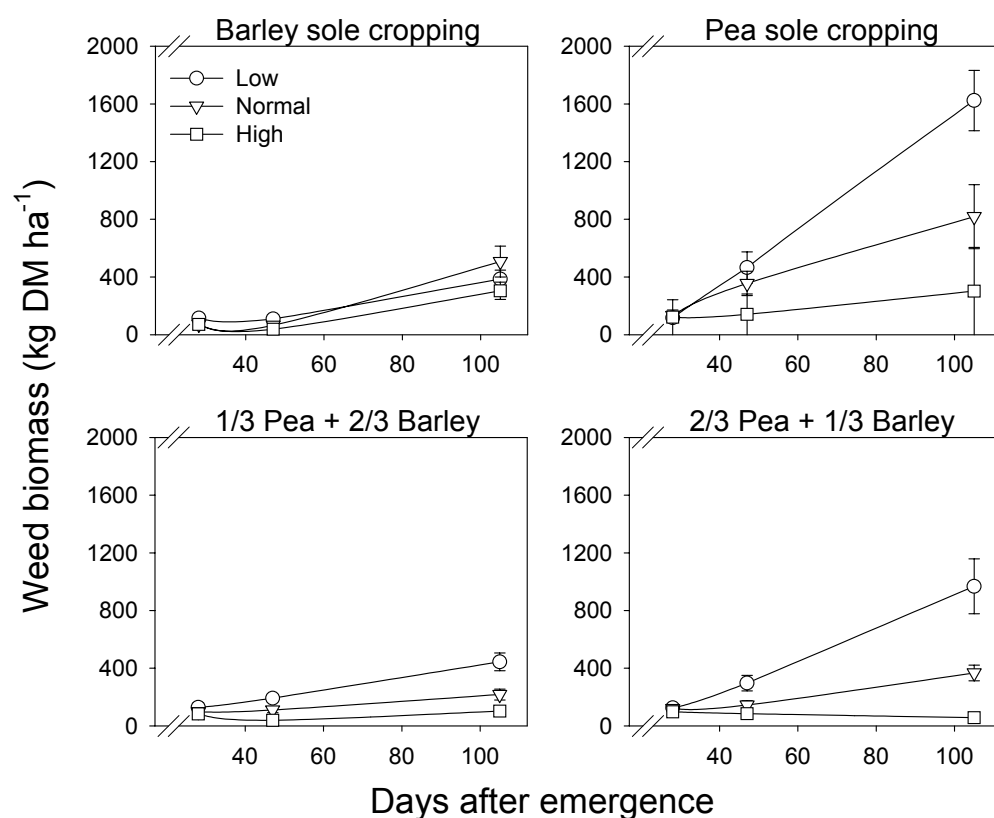
A greater proportion of pea than barley was observed in the intercrop when increasing the density, but the sole crop grain yields were not significantly influenced. Contrary to the density treatment the intercrop relative frequency determined the quantity of the two species in the final yield. The use of an additive design increased the pea proportion in the intercrop compared to the replacement intercrops. The total grain yield was not significantly different when comparing treatments. Thus, relative frequency, density and design seem all to be methods for regulating the interspecific competition regarding yield quality but not quantity. but with a tendency to have a lower yield in the high density plots due to lodging. However, it is important to consider the differential performance of intercrop components at different locations and cropping systems as observed in WP3 task 1.

In cropping systems with high weed pressure it is crucial to have a strong crop competitive ability towards weeds. In this study the biomass of weeds was greater under pea than under barley sole crops (Fig. 4). This was in accordance with observation of less competitive ability towards weeds in the intercrops with higher proportion of pea, especially in the low-density treatments. Sole cropped pea

increased its competitive ability towards weeds with increasing density, whereas barley showed the same competitive ability independent of density. Barley has an ability to regulate its tillering ability according to space and resources available. Weed biomass in intercrops was significantly reduced when the density of pea and barley was increased. In general, the present study shows that a higher complementarity in pea-barley intercrop plant communities compared to pea sole cropping may provide an ecological method utilising competition and natural regulation mechanisms to manage weeds (Figure 4).

There was a resource complementarity (Land Equivalent Ratio > 1) in all the density and design combinations. Intercrop components compete only partly for the same plant growth resources and interspecific competition was less than intraspecific competition. The complementarity between pea and barley was greatest in the intercrop with the high pea frequency in the low density treatment minimising intercrop competition. It was expected that the additive design induced the most productive intercrops and thereby the most efficient use of resources. However, using LER no difference between replacement and additive design was observed. Significantly lower barley seed weights were measured when increasing the density independent of cropping strategy. The same observation was made when changing from replacement to additive design.

The preliminary conclusion is that basic management tools such as intercrop component relative frequency, crop density and intercrop design seem all valuable, when using intercropping to manage weed problems in organic cropping systems while maintaining crop yields.



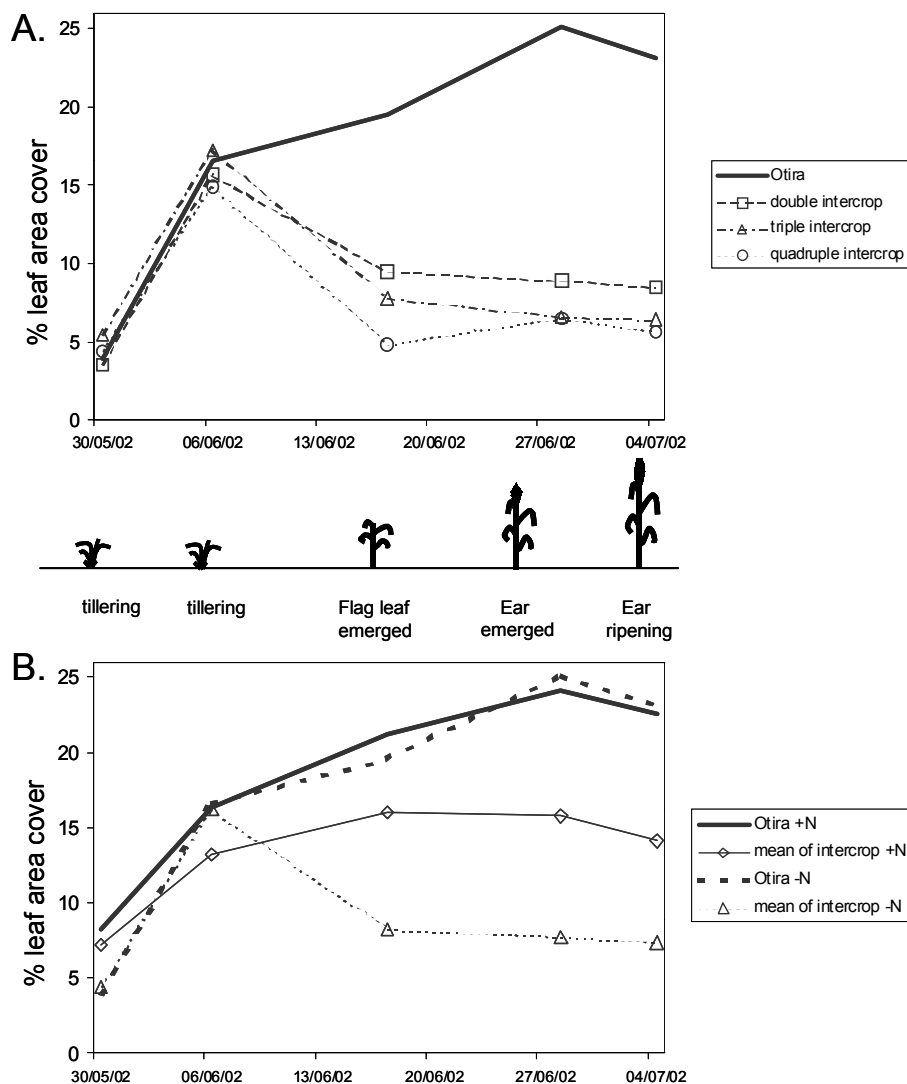
**Fig. 4.** Effect of intercropping pea and barley at three densities on weed biomass development. The crop species were grown at 50 (low), 100 (normal) and 200% (high) of the recommended density at two intercrop relative frequencies (1/3 pea+2/3 barley and 2/3 pea + 1/3 barley) in 2001.

#### **WP4. Plant health in grain legume and cereal crops**

Our objectives were to determine 1) how intercropping systems of grain legumes and cereals affects the establishment and development of relevant diseases, and 2) to achieve a better understanding of how availability of nutrients affect disease resistance mechanisms in an organic farming system.

**Task 1.** The effect of barley-legume intercrop on disease incidence was investigated over two years in two locations (Højbakkegård and Jyndevad). Several diseases were observed: ascochyta blight (*Mycosphaerella pinodes*) on pea, brown leaf spot (*Plieochaeta setosa*) on lupin and chocolate spot (*Botrytis*) on fababean. On barley net blotch (*Pyrenophora teres*), brown rust (*Puccinia hordei*) and powdery mildew (*Blumeria graminis* f. sp. *hordei*) (in order of incidence) were detected. A general reduction in disease was observed in all intercrop systems compared to the corresponding monocrop (Fig. 5A). The reduction was larger in magnitude 1) for splash dispersed diseases (brown leaf spot on lupin, Ascochyta blight on pea and net blotch on barley) compared to wind dispersed diseases, 2) when crops were of similar height, 3) when the accompanying crop had many large leaves i.e. full leaf pea gave larger reduction than semi-leafless pea and 4) when there were three or four components in the intercrop compared to only two.

The above sole crop and intercrop systems were also grown with 50 kg N added as urea and monitored under the same field conditions. The presence of added nitrogen increased levels of mildew and rust (biotrophic fungi). The effects of the intercrop on disease were similar regardless of nitrogen application for all diseases except net blotch. In the presence of added N the reduction in net blotch was significantly less than when no extra N was added (5b).



**Figure 5**

A) Disease severity (% leaf cover) of net blotch on barley cv. Otira grown as a monocrop, or in a double, triple or quadruple intercrop with grain legumes in Højbakkegård. Disease level was reduced when barley was grown in an intercrop.

B) Comparison of net blotch severity of net blotch on barley grown as a monocrop or intercrop in the presence or absence of added nitrogen. In the presence of added nitrogen the reduction in net blotch was significantly less than when no extra nitrogen was added.

**Task 2.** Glasshouse experiments on the effect of the availability of N, P or K disease resistance mechanisms were set up. Barley was grown under different nutrient conditions (depletion of N, P or K). Plants were infected with powdery mildew at the third leaf stage. Initial results showed that plants depleted of nitrogen had increased resistance to the fungus (effective at penetration). Absence of phosphorous appeared to increase penetration of powdery mildew but the resulting colonies were smaller than control. Depletion of K appeared to increase fungal penetration.

It is concluded that:

- Barley-grain legume intercropping reduced disease incidence.
- The presence of added N decreased the magnitude of this reduction for one disease.
- Added N increased incidence of biotrophic pathogens.
- The nutrients N, P and K have clear distinct effects on disease resistance mechanisms.

## WP5. Quality aspects

The nutritional quality of seeds from the first growing season (2001) of sole and intercrops of cereals and legumes has been investigated (see WP3 task 1). The seeds were analysed for ash, crude protein, crude fat, starch and enzyme digestible organic matter. Furthermore, on selected samples the effect of protein level on the amino acid composition in each crop was investigated.

The results show that intercropping has a positive effect on the protein content of barley, in particular of the high-lysine barley (Table 4). Furthermore, the positive effect was much more pronounced at Højbakkegaard than at Jyndevad.

The effect of extra N-fertilisation at Højbakkegaard was much less pronounced than the effect of intercropping. However, the effect of extra N-fertilisation was only based on one sample from each variety and is therefore not included in the table.

Generally, the starch content is negatively correlated to the protein content, i.e. a higher protein content result in a lower starch content. Furthermore, the organic matter digestibility (EFOS) appears to be related to the protein content. Thus, samples with higher protein content were generally higher in the organic matter digestibility.

The results in Table 5 show that the protein content in pea was markedly higher in samples from Jyndevad than from Højbakkegaard. This was also the case for faba beans, whereas there was no difference between the samples of lupin. Also in the legume seeds the starch content is negatively correlated to the protein content whereas the organic matter digestibility is positively correlated. The more constant protein level in lupin may be related to the almost lack of starch in this species.

Amino acid analyses of seeds with lowest and highest protein content showed that the protein quality is significantly influenced by protein level in the barley and legume seeds. Generally, the lysine concentration in protein was found to be highest in samples with low protein content in barley and legumes, whereas the arginine concentration was highest in samples with high protein content in all legume seeds, but not in barley. Glutamic acid + glutamine concentration was significantly increased in the normal barley variety with high protein content, but not for the high-lysine barley and the legumes.

A total of 470 samples have been analysed for total N and <sup>15</sup>N abundance.

**Table 4.** Effect of intercropping and location on barley chemical composition

### a) Barley (Otira)

	Højbakkegaard		Jyndevad		Total	
	Monocrop	Intercropping	Monocrop	Intercropping	Monocrop	Intercropping
N	2	4	3	3	5	7
Ash	2,2 ± 0,0	2,4 ± 0,3	2,6 ± 0,5	2,4 ± 0,0	2,4 ± 0,4	2,4 ± 0,2
Protein	10,0 ± 0,6	12,1 ± 2,2	10,0 ± 1,1	10,4 ± 0,1	10,0 ± 0,8	11,5 ± 1,8
Fat	3,7 ± 0,1	3,7 ± 0,2	3,3 ± 0,1	3,3 ± 0,1	3,5 ± 0,2	3,5 ± 0,3
Starch	59,1 ± 0,2	56,5 ± 2,2	54,6 ± 2,6	55,6 ± 1,2	56,4 ± 3,1	56,1 ± 1,8
EFOS	82,5 ± 0,1	83,4 ± 0,2	79,8 ± 0,1	82,3 ± 0,5	80,8 ± 2,0	82,9 ± 0,3

**b) Barley (Lysiba)**

	Højbakkegaard		Jynde vad		Total	
	Monocrop	Intercropping	Monocrop	Intercropping	Monocrop	Intercropping
N	2	4	3	3	5	7
Ash	2,3 ± 0,0	2,6 ± 0,2	2,3 ± 0,1	2,5 ± 0,1	2,3 ± 0,1	2,5 ± 0,1
Protein	12,0 ± 0,9	15,2 ± 0,5	10,4 ± 0,3	11,8 ± 0,5	11,4 ± 1,1	13,2 ± 1,9
Fat	5,5 ± 0,1	5,3 ± 0,4	4,4 ± 0,2	4,4 ± 0,2	5,1 ± 0,6	4,8 ± 0,5
Starch	53,4 ± 0,9	50,3 ± 1,5	54,1 ± 1,3	52,6 ± 1,3	53,7 ± 1,0	51,6 ± 1,7
EFOS	83,3 ± 0,5	83,3 ± 0,4	82,2 ± 0,1	81,8 ± 0,7	82,9 ± 0,7	82,4 ± 1,0

**Table 5.** Chemical composition of the investigated legumes**c) Pea (Bohatyr)**

	Højbakkegaard	Jynde vad	Total
N	3	3	6
Ash	3,0 ± 0,0	2,8 ± 0,0	2,9 ± 0,1
Crude protein	23,4 ± 1,4	31,0 ± 0,3	27,2 ± 4,3
Crude fat	2,6 ± 0,1	2,4 ± 0,1	2,5 ± 0,1
Starch	43,1 ± 0,4	36,6 ± 0,6	39,9 ± 3,6
EFOS	87,4 ± 2,9	90,6 ± 1,2	89,0 ± 2,7

**Lupin (Prima)**

	Højbakkegaard	Jynde vad	Total
N	3	3	6
Ash	3,8 ± 0,2	4,2 ± 0,2	4,0 ± 0,2
Crude protein	34,1 ± 1,2	34,9 ± 1,8	34,5 ± 1,4
Crude fat	6,8 ± 0,5	6,2 ± 0,4	6,5 ± 0,5
Starch	0,6 ± 0,0	0,2 ± 0,0	0,4 ± 0,2
EFOS	91,1 ± 1,0	89,4 ± 0,6	90,2 ± 1,2

<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	
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	
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	
<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 ideo-types 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	
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	
<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	
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	
<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	Not finalized before end of spring 2002

2 Results from field experiments year 2	Ultimo 2002	Not finalized before spring 2003
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	
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	
2 Paper about influence of nutrient uptake on disease resistance (May 2003)	2003	
<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 Jan 2003 Dec 2003	
<b>Milestones</b>		

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*

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

### WP2 task 3.

It has so far not been possible to perform the planned field experiments. Birds, despite intensive precaution by electrical alarms and netting, have destroyed the experiments. It must be concluded that within the given budget in this project it is not possible to grow grain legumes in this long term experimental unit concerning long time effect of increasing application of N, P and K, because it covers a field of more than 300 m length and because the area is under heavy bird damage pressure. An alternative to this field set-up is greenhouse pot experiments, where soil is taken from the low P-level plots and control areas. This testing of N uptake and N fixation at varying P soil level is planned during the winter 2002-2003 and spring.

## E. Project publications and other products

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

\*\*Hauggaard-Nielsen H, Ambus P and Jensen E S (2002). The comparison of nitrogen use and leaching in sole cropped versus intercropped pea and barley. *Nutrient Cycling in Agroecosystems* (in press)

\*\*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.

Kinane, J. and Lyngkjaer, M. 200x. Effect of Barley-Legume Intercrop on Disease Frequency in an Organic Farming System. *Plant Protection Science* (submitted)

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

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,

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.

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.

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.

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.

### **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 environment-friendly and sustainable European agriculture. Grain Legumes 36,

\*\*Duranti, M. and Jensen, E.S. 2001. Progress in grain legume R&D – outputs of the 4th European Conference on Grain Legumes. Grain Legumes, 34: 12-13.

Hauggaard-Nielsen, H., Jørnsgaard, B. Jensen, E.S. 2002. Arealet med frøbælgplanter bør øges. Landsbladet 4.

\*\*Jensen, E.S. 2002 Linser på danske middagsborde? Økologisk Jordbrug 2002

\*\*Jensen, E.S. 2002 Forbrugerne må træffe sit eget valg. Debat indlæg (Synspunkt) om økologisk fødevarer i Søndagsavisen d. 9.6. 2002, s. 2

\*\*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

\*\*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 visit**

Askegaard, M. 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 advisers in June 2002.

Hauggaard-Nielsen H. 30 May 2002 Visit from The Danish Family Farmers' Association on Sealand showing organic farmers the GENESIS activities.

Hauggaard-Nielsen H. 20 June 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.

Hauggaard-Nielsen H. and Jørnsgaard B 30 July 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.

Hauggaard-Nielsen H. 25 June 2002 Visit from Danish Institute of Agricultural Sciences field staff responsible for organic trials at Foulum, Jyndevad and Flakkebjerg Experimental stations.

Jørnsgaard J. Field visit at KVL. Slagelse Tekniske skole, 29. August 2001

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

Jørnsgaard J. Field visit at KVL20. June 2001.

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

#### **Seminar arranged**

Hauggaard-Nielsen H. 24 June 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. 15 people were participating.

### Oral presentations

Hauggaard-Nielsen H. (2002) Blandingsafgrøder med korn og bølgsæd – erfaringer og nye udfordringer. Thematic field day at the Organic Research Farm Rugballegård, Danish Institute of Agricultural Sciences, 6 August

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 Jyndevad, Danish Institute of Agricultural Sciences, 19 June. The talk was followed up with some practical exercises using the GENESIS field trials.

Hauggaard-Nielsen H. (2002) Dyrkning af blandinger og høstteknologi. Talk to developer, technicians and salesmen at NewHolland, 19 April

Hauggaard-Nielsen H. (2002) Blandsæd – bland afgrøderne og høst fordele. Talk to DLG-Økologi salesmen following a course in Organic Farming at FAF Odense, 16 January.

Hauggaard-Nielsen H. (2001) Dyrkning af blandingsafgrøder med bælgssæd. Thematic workshop at Snohøj IT Folkehøjskole titled " Proteinafgrøder i økologisk Jordbrug – dyrkning og fodring", 28 November

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

Jørnsgård B. 2002. Nyt om lupin dyrkning fra ind- og udland. Præsentation ved DLG dag. 30 juli, Statsfængslet Kjærshovedgård, Ikast.

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

Sarasua, M. 2002. Intercropping of fababean with barley, pea and oil seed rape. MSc thesis, June 2002, KVL.

## 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.

MSc student Ms. Knudsen has carried out her MSc in relation to WP3 task 1 field trial at KVL and Jyndevad.

Two MSc students, Ms. Muguerza and Mr. Sarasua both from Pamplona, Spain have carried out their MSc projects in the research group at KVL.

MSc student Mr. Nikolajsen and Ms. Ravnborg are currently carrying out the their MSc thesis in relation to the project at KVL.

## G. National and international cooperation

### National

Collaboration with other research projects and scientist in the previous and the new DARCOF pro-

gramme 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 Hauggaard-Nielsen, H. KVL research group and deputy head Møller, L.F. ([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.

Henrik kan vi ikke skrive noget om dit samspil med DLG-Økologi ?

A joint project meeting with the new DARCOF project GRANLEG, focusing on grain legume diseases, was established in June 2002. It is planned to have an annual joint meeting with interested participant from the grain legume integrated chain outside the projects. There will be additional separate project meetings.

### **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. Henrik Hauggaard-Nielsen is also involved in the activities of AEP.

ESJ, PA and SB submitted a proposal for the 5 FP in EU in January 2002 with University of Kassel, Witzenhausen (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 with ESJ as the coordinator. The contract is being prepared.

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.

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

In September 2002 the European Parliament agreed to recommend to the Commission that EU should implement a strategy to increase the European production of feed protein in order not to be dependent on the import of Soya from the American continent. The GENESIS project appears to be very timely considering the requirement for self-sufficiency in organically produced feed protein and energy in Denmark and Europe. The relatively greater focus on grain legumes than cereals seems to be justified since the organic cereal production has increased significantly in recent years and there seems to a surplus in 2002. It appears from the list of products that the dissemination of project activities has been intensive and there is a lot of interest from farmers and the industry.

The project was constructed by merging various expressions of interest. Certain scepticism was observed among the participants regarding this project construct, but it has been very useful to meet and collaborate colleagues within new areas. It appears that there is a good interaction between the different workpackages and participants request even more interaction. In the next project meeting in January 2003 we will discuss how this can be accomplished.

Carrying out field experiments related to plant nutrition and soil fertility in experimental farms with rotations, which may not resemble organic rotations, may cause problems and erroneous estimates/conclusion. As an example the precrop and fertility management may influence estimates of biological N<sub>2</sub> fixation due to the amount of soil available N. As a consequence of this and the increasing focus on grain legume research, KVL has now changed its organic rotation to include a grain legume crop.

### **Reflections participants**

#### ***Bjarne Jørnsgaard (WP1 and 2).***

The present program investigate highly important aspects and possibilities for increasing the grain legume area, yield and stability in organic farming, with respect to weed control, nitrogen dynamics choice of varieties and species, leaf diseases etc. However, an increase proportion of grain legumes in the organic rotations raise the question of rotational diseases in the grain legumes. Will fusarium and other soil borne diseases in the grain legumes restrict the proportion of the faba bean, peas and lupins in the rotation or can the three species fit into the same rotation without causing problems for each other. The importance of this problem will increase with the success of the present project, and it is undertaken in a new FØJO programme "Grainleg". The GRAINLEG programme can hopefully provide results concerning resistance and cross patogenicity which will allow for a significant increase in the grain legume area based on the results in the present GRAINLEG programme.

#### ***Henrik Hauggaard-Nielsen (WP3)***

The downward tendencies on cereal marked prices and the 2005 regulation for protein self-sufficiency strongly picture the intact project objectives. Results from the first year GENESIS experiments was widely presented and discussed within farmer communities and industries emphasizing a strong interest and requirement for knowledge about how to increase grain legume protein production. The area cropped with grain legumes in 2002 is considerable increased compared to just one year ago and we believe that the GENESIS research group plays a central role in this rapid development together with e.g. the on farm protein project initiative from the organic crop production trade association and the new contract production initiative from DLG-Økologi. The implementation of the GRAINLEG research group in a yearly combined research meeting is another initiative expecting to strengthen a more transverse research synergy towards an improved holistic understanding of grain legume cropping system including yearly as well as rotational matters.

The <sup>15</sup>N natural abundance method was applied to the 3-year experiment conducted on two different locations. This method is cheaper than the <sup>15</sup>N-enrichment techniques because no pre-treatment of <sup>15</sup>N-enriched material is necessary and where natural abundance and <sup>15</sup>N enrichment techniques have been compared, field estimates of N<sub>2</sub> fixation is often similar, with similar precision. However, on the sandy soil the level of natural <sup>15</sup>N abundance in the soil was low, giving a minimum difference of δ<sup>15</sup>N between the barley reference crop and legume of approximately 1‰ indicating that the estimates should be handled with care. A greater atmospheric N deposition in combination with some unexpected soil characteristics might explain this. In order to secure grain legume N<sub>2</sub>-fixation estimates it might have been valuable to include expenses for using the <sup>15</sup>N enrichment technique.

#### ***Julia Kinane (WP4)***

I think it was an excellent idea to have several groups looking at the same trials. It's a more efficient use of resources; the trails are probably more comprehensive than if we each had our own and our results can compliment and sometimes explain one another. I feel it could be better if the groups would have more time to discuss our results with one another. By that I mean either have longer meetings or have meeting more frequently, (especially important once the results are collected and analysed).

#### ***Sigurd Boisen (WP5)***

The chemical composition - and thus the nutritional quality - of the different crops are influenced by many factors, including the soil type and fertilisation at the different locations. Thus, the rather cold and wet weather during the first growing season (2001) that delayed the sowing at Jyndevad with one to two months resulted in a generally rather poor crop development and grain yield at this location. Therefore, the chemical composition may be significantly influenced by the specific climatic conditions this year.

The analyses were only performed on 1/4 of the total number of collected samples, due to the limited budget for this task. Therefore, the number of samples from the individual legumes was too low to study eventually effects of intercropping on their chemical composition. The additional analyses of samples for the following two growing seasons will make a better basis for this. Furthermore, the strategy for analyses of samples from the following two years may be changed to focus more on protein and starch, which may be the only of the investigated nutrients that vary significantly.

## 8. Budget

### A. Account for any change in budgets

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

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

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	34.6	37.3	32.2			104.1
Technical personnel	18.2	21.5	12			51.7

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	1122	1234	1145			3501
Technical personnel	314	317	180			811
Other operational costs	374	456	265			1095
Equipment		5	1			6
Others (please specify)	23	21	17			61
Direct costs	1833	2033	1608			5474
Indirect costs (20% of direct costs)	367	407	322			1095
Total	2200	2440	1930			6570

**Comments:**

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## 9. Signatures and stamps

Name	Institute	Date	Signature
Head of project Erik Steen Jensen	KVL	23 September 2002	

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## Appendix I. Detailed budget

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

#### Name of Institute:

KVL

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	23.5	20	18			61.5
Technical personnel	7.5	10	6			23.5

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	764	662	636			2062
Technical personnel	164	24	48			236
Other operational costs	179	323	157			659
Equipment						
Others )			10			10
Direct costs	1107	1009	851			2967
Indirect costs (20% of direct costs)	221	201	170			592
Total	1328	1210	1021			3560

#### Comments:

**Name of Institute:**  
DIAS

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	3	4	5.7			12.7
Technical personnel	8.5	8.5	4			21

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	102	143	223			468
Technical personnel	96	217	78			411
Other operational costs	147	53	65			265
Equipment		5	1			6
Others (analysis)	23	21	7			51
Direct costs	368	439	374			1181
Indirect costs (20% of direct costs)	73	88	75			236
Total	441	527	449			1417

**Comments:**

**Name of Institute:**

Risø

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	8.1	13.3	8.5			29.9
Technical personnel	2.2	3	2			7.2

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	256	429	286			971
Technical personnel	54	76	54			184
Other operational costs	48	80	43			171
Equipment						
Others (please specify)						
Direct costs	359	585	383			1327
Indirect costs (20% of direct costs)	71	117	77			265
Total	430	702	460			1592

**Comments:**

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

### Name of Institute and department:

Organic Farming Unit, Department of Agricultural Sciences, KVL

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	12	12	12			36
Technical personnel	3	6	4			3

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	367	422	445			1234
Technical personnel	74					74
Other operational costs	125	215	142			482
Equipment						
Others (please specify)			10			10
Direct costs	566	637	597			1800
Indirect costs (20% of direct costs)	113	127	119			359
Total	679	764	716			2159

### Comments:

According to the KVL Accounts Departments' procedures some of the technical personnel salaries are transferred to other operational costs in the budget calculations. In the 2002 and 2003 budgets all expenses to technical help is kept as operational costs. Thus, man month indications may be a bit misleading.

From the 2001 budget 21.000,- DKK of the grant was send back to the [Ministry of Food, Agriculture and Fisheries](#) due to less consumption than expected caused by a delay in payment of a bill. The bill was paid after finalizing the financial year. Together with 10000,- dkk from the 2002 budget WP3 apply for a total transfer of these money to the 2003 budget to be used for further quality analysis of grain legume and cereal seeds when comparing sole cropping and intercropping strategies.

**Name of Institute and department:**

Section of Plant breeding and Crop Science, Department of Agricultural Sciences,  
KVL

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	11,5	8	6			25,5
Technical personnel	4,5	4	2			10,5

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	397	240	191			827
Technical personnel	90	24	48			162
Other operational costs	54	108	15			177
Equipment						
Others (please specify)						
Direct costs	541	372	254			1167
Indirect costs (20% of direct costs)	108	74,4	50,6			233
Total	649	446,4	304,8			1400,4

**Comments:**

The decrease in expected consumption in 2002 of technical personal and the corresponding increase in other operational costs is caused by a change in the Invoice from the Royal Veterinary and Agricultural University Experimental Farm Unit, where the chemical analysis and field assistance is not any more specified as technical hours but as a service and therefore placed under other operational costs.

Danish Institute of Agricultural Science, Department of Crop Physiology and Soil Science.

Year: 2002 <b>WP 2</b>	Con- sumption before 2002	2002	2003	2004	2005	Total
Man-months						
Scientific personnel	2	3	4			9
Technical personnel	6.5	5.5	1			13

Year: 2002 <b>WP 2</b>	Con- sumption before 2002	2002	2003	2004	2005	Total
Salaries						
Scientific personnel	71	112	169			352
Technical personnel	52	147	8			207
Other operational costs	125	10	32			167
Equipment		5	1			6
Others :						
Extern analyses	20	18	4			42
Travels	3	3	3			9
Direct costs	271	295	217			783
Indirect costs (20% of direct costs)	54	59	44			157
Total	325	354	261			940

**Name of Institute and department:**  
DJF, Animal Nutrition and Physiology

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	1	1	1,7			3,7
Technical personnel	2	3	3			8

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	31	31	54			116
Technical personnel	44	70	70			184
Other operational costs	22	43	33			98
Equipment						
Others (please specify)						
Direct costs	97	144	157			398
Indirect costs (20% of direct costs)	19,4	28,8	31,4			79,6
Total	116,4	172,8	188,4			478

**Comments:**

**Name of Institute and department:**  
Risø, Plant Genetics and Epidemiology

Year:	Consumption before 2002	2002	2003	2004	2005	2006	Total
Man-months							
Scientific personnel	8	13	8				29
Technical personnel	2	2	1				5

Year:	Consumption before 2002	2002	2003	2004	2005	2006	Total
Salaries							
Scientific personnel	252	417	269				938
Technical personnel	49	51	26				126
Other operational costs	40	50	12				102
Equipment							
Others (please specify)							
Direct costs	342	518	307				1167
Indirect costs (20% of direct costs)	68	104	62				233
Total	410	622	369				1400

**Name of Institute and department:**  
Risø, Plant Environment Interactions

Year:	Consumption before 2001	2001	2002	2003	2004	2005	Total
Man-months							
Scientific personnel		0,1	0,3	0,5			0,9
Technical personnel		0,2	1	1			2,2

Year:	Consumption before 2001	2001	2002	2003	2004	2005	Total
Salaries							
Scientific personnel		4	12	17			33
Technical personnel		5	25	28			58
Other operational costs		8	30	31			69
Equipment							
Others (please specify)							
Direct costs		17	67	76			160
Indirect costs (20% of direct costs)		3	13	15			32
Total		20	80	91			192