Danish Research Centre
for Organic Farming

Final Report

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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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Slutrapporten sendes elektronisk til Forskningscenter for Økologisk Jordbrug *foejo@agrsci.dk* senest 3 måneder efter projektets afslutning.

Slutrapporten vedlægges et dansk resumé.

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6. Project period (month, year)

Start of project: September 2000
End of project: March 2004

7. Final report

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_2 fixation and by their effect as break-crop for cereal diseases in rotations. However, grain legumes have the reputation of high yield variability, due to low tolerance to water stress and lodging for some species, late maturity for others and variability of the seed quality.

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

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

Table A: 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	BJ, ESJ, HHN	1400	April 2000	Mar. 2004	1-4
2	Performance of grain legumes and cereals at low K and P levels	MA, BJ,	940	April 2000	Mar. 2004	5-8
3	Intercropping of grain legumes and cereals: resource use and weed management	ESJ, HHN, BJ, MTK	2160	Feb. 2001	Mar. 2004	9-13
4	Plant health in relation to intercropping and nutrient uptake	ML, JK	1400	Feb. 2001	Mar. 2004	14-16
5	Quality of grain legumes and cereals and isotope analysis	KEBK, SB, PA	670	Sept. 2001	Mar. 2004	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, fababean 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 sole cropping 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 utilising P from soils low in available P.

WP3. Intercropping of grain legumes and cereals: resource use and weed manage-

ment

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 sole crops on two soil types, and
- determine the competition and use of multiple resources in intercrop/weed and sole crop/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 sole crops.

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 sole crops. 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, fababeans and narrow-leaf lupines grown as sole crops 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. Progress and results

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 experiment was carried out on a sandy loam soil in two seasons. Twenty-eight pea (*Pisum sativum* L.), 12 fababeans (*Vicia faba* L.), 8 lupin (*Lupinus* spp.), 11 spring barley (*Hordeum vulgare* L.), 10 spring triticale (*Triticosecale*) and 8 spring wheat (*Triticum sativum* L.) cultivars were tested in sole and intercropping, in sole crops and in 50%:50% mixed intercrops. The grain legumes were tested in intercrop with one standard spring barley cultivar cv. Otira and the cereals were tested in intercrop with one standard pea cultivar cv. 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 seasons. All plots were combined harvested and representative genotypes within each species were hand harvested for determination of total biomass and harvest index for the different combinations of species and cultivars. In year 2000 short stem peas and early ripening narrow leafed lupins with restricted branching were the best option for intercropping with spring barley and -wheat, with respect to synchronized development and standing ability. Traditional branched lupins and fababeans outgrew and ripened much later than the intercropped cereals. Weed infestations in the intercrops were comparable 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 late April. The significant differences between species observed in year 2000 in development and ripening time was remarkable reduced in this season due to a warm dry august, which forced even the fababean to ripen. Cultivar 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. Intercropping did not influence the patterns of height growth of the different varieties significantly and could neither be related to differences in competitive ability towards companion crops or weeds.

Cereals 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 approx. 30% in wheat, barley and triticale, when intercropped with fababean and peas compared to sole crop cereal, whereas the response to lupins was significantly lower with an app. 10% increase.

Conclusion

Barley, spring wheat and triticale intercropped with tested pea cultivars and the earliest reduced branching types of lupins resulted in harmonic intercrops with respect to synchronous development and ripening. Risk for significant differences in ripening exist in intercrops of cereals with fababean and highly branched lupins. The highest total grain yield was found for the pea-barley intercrops, whereas the highest protein yield was observed in the lupin sole crops. The yield and protein increase that was found in the intercrops of cereals mixed with pea or fababean were not observed in the intercrops of lupin with barley. The reduction in weed infestation due to intercropping with cereals was the same in all legume species, which is of particular importance for week competitors as fababeans and non-branching lupins (Table 1).

Table 1. Grain and protein yield, protein concentration (protein= Nx6.25) and weed infestation of sole crops and intercrops of cereals and grain legumes in the cultivar experiment 2001 at Højbakkegaard.

Cereal species	Legume species	grain yield total gm^{-2}	grain yield cereal gm^{-2}	grain yield legume gm^{-2}	grain protein total gm^{-2}	grain protein cereal %	grain protein legume %	Weed gm^{-2}
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
-	faba bean	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	faba bean	411	212	199	80	11.7	28.1	23
barley	lupin	394	245	149	72	8.8	34.0	19
$Lsd._{0.05}$		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 experiments were carried out at a sandy loam soil location (Højbakkegård; 55°40’N, 12°18’E) and a sandy soil location (Jyndevad; 54°54’N, 9°8’E) during the 2001-2003 seasons. One genotype of faba bean (*Vicia faba* var. *minor* L., cv. Columbo), one narrow-leafed non-brancing lupin (*Lupinus angustifolius* L., cv. Prima), a semi-leafless and a normal leafed pea cultivar (cv. Agadir and cv. Bohatyr, respectively) and a standard feed barley (cv. Otira) and a high lysine cultivar (cv. Lysiba) was selected for the experiment based on the results in WP1 task 1. These cultivars were grown as sole crops at recommended sowing rate. The trial was each year placed equivalent to a second year cereal in a traditional rotation to get a medium to low soil mineral N availability to picture normal farmer practise for grain legume cropping and on the same time secure growth and thereby competitive interactions of both barley and grain legumes in an intercrop. The experiment is integrated in the experiment described in WP3 task 1.

There was a highly significant variation in biomass production, grain yield, total nitrogen accumulation, protein content and weed infestation over location, years and crops. The highest grain yield was obtained in peas on the sandy loam, where the tested semi-leafless cultivar cv. Agadir yielded 5.2 t grain ha^{-1} in average over the 3 years, 13% more than the normal leafed cv. Bohatyr at the sandy loam soil. At the sandy soil their yields were comparable with 4.4 and 4.3 t grain ha^{-1}, respectively. Fababean and lupin had both a yield of 3.4 t grain ha^{-1} in the sandy loam soil, with decreasing yields of 3.2 and 2.7 t grain ha^{-1} on the sandy soil, respectively at the sandy soil. The yield of lupin at the sandy loam soil was the results of yields of 4.2, 4.3 and 1.7 t grain ha^{-1} in year 2001, 02 and 03; the latter yield due to the use of an ineffective commercial *Bradyrhizobium lupini* strain. The feed barley cv. Otira yielded 2.8 and 2.5 t grain ha^{-1} without N-fertilization, compared to 2.1 and 2.4 for cv. Lysiba at the sandy loam and sandy soil, respectively. After application of 50 kg urea-N ha^{-1} the yield of cv. Otira was raised more than 50% and of cv. Lysiba app. 40% at both locations (Table 2).

At the sandy loam soil the highest yield stability was observed for the peas, whereas the barley yield was very variable, especially at the low N level. Fababean and lupin had lower yield stability than pea and fertilized barley. In contrast, at the sandy soil the highest yield variability was observed in the pea cultivars and fababean and the lowest in lupin and barley, where the application of urea-N increased the yield variation significantly (Table 2).

Crop nitrogen balances were determined to evaluate the effect of cropping on soil N fertility. The balance includes fixed N accumulation in belowground plant parts for each grain legume species according to Mayer et al. (2003). Nitrogen fixation was very constant in grain legume sole crops over species and location, varying from 13.2 g m^{-2} to 15.8 g m^{-2} (Table 5) being lowest in peas and highest in faba bean and lupins. The resulting crop N balance after subtracting N removed in the harvested grain were +2 g m^{-2} for both pea cultivars at both soil types and +3.5 g m^{-2} for the fababean and lupin. In barley the crop N balances were all negative ranging from in average –3.5 g m^{-2} at both soil types without urea-N application to near 0 after application of 50 kg urea-N ha^{-1}.

The weed biomass was 4 times lower at the sandy compared to the sandy loam soil, mainly due to heavy infestation of red clover (*Trifolium pratense*) in 2002 at the sandy loam soil. Weed infestation in the different crops were comparable, however it tended to be highest in fababean, lupin and unfertilised barley, where the application of urea reduced the weed infestation by around 50% (Table 2).

The grain quality varied over location and species. The nitrogen content in the barly grain tended to be higher at the sandy soil as compared to the sandy loam soil, in contrast the grain legumes nitrogen content was highest at the sandy soil. The peas had an average nitrogen level of 3.6%, the faba bean 5% and the lupins 5.3%. The Lysiba barley cultivar had a N concentration in the grain which was 0.2% higher then the feed barley cv. Otira, and it responded to increased N level by a larger increase in grain N concentration compared to cv. Otira, which responded by a higher increase in total grain yield.

Conclusion

Despite high yield variability at the sandy soil for peas, the highest yield independent of location was achieved by growing peas. Yield stability is highest for peas at the sandy loam soil and for barley and lupin at the sandy soil, and lowest for barley at the sandy loam soil and peas and fababean at the sandy soil. As the quantity of N in the harvested grain and the amount of fixed nitrogen is slightly lower for peas than for fababean and lupins, the N balance is lower for the peas although still positive meaning that grain legumes has a net contribution of N to the soil.

Task 3. Ideotypes for intercropping and weed suppression ability

Narrow leafed lupin is used as a model crop to access to genetic diverse material with respect to branching structure and time of stem elongation. The lupins were grown at 100 plants per m^2 in intercrops with one barley cultivar (cv. Otira) sown at 50 plants per m^2 in two seasons.

In 2001 barley dominated the intercrop and the different forms of lupin growth (branching structure and time of elongation) had only minor effect on the weed control. Furthermore, the differences in time of ripening between lupin cultivars with different forms of growth were significantly reduced compared to expectations. In 2002 when both barley and lupins had reduced growth due to soil mineral N limitations and poor nodulation of lupins, the lupins dominated over barley. Furthermore the experiment was heavily infected by weeds (red clover) which overgrew the barley and many lupin cultivars and consequently the lupin growth form was decisive for the weed control and only branched tall lupins gave an acceptable weed control. Differences in time of ripening observed in lupin sole crops were also observed in the intercrops with cereals where lupins dominated.

Significant differences in barley yield components were observed in the first year, when barley was intercropped with the different lupin ideotypes. The total biomass of barley was not affected significantly, however, there was a tendency for higher barley biomass in intercrops with the most reduced branching lupins. 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 ideotypes due to a reduction in barley seed weight by 20% and in total grain number by 30% (Table 3). Both the highest total grain yield

Table 2. Grain yield and coefficient of variation, legume seed proportion weed infestation in

sole crops and intercrops of grain legumes and cereals at Højbakke and Jyndevad over 3 years.

		Total grain yield Average of 3 years				Legume proportion		Total grain yield Hojbakke			Total grain yield Jyndevad			Weed bio-mass	
		Hoj	Hoj	Jyn	Jyn	Hoj	Jyn	2001	2002	2003	2001	2002	2003	Høj	Jyn
Average of 3 years		gm^{-2}	c.v.	gm^{-2}	c.v.	%	%	gm^{-2}	gm^{-2}	gm^{-2}	gm^{-2}	gm^{-2}	gm^{-2}	gm^{-2}	gm^{-2}
Pea semi leafless	Agadir	522	19	438	37	100	100	478	471	620	267	442	606	94	44
Pea normal leaf	Bohatyr	462	25	427	38	100	100	502	402	483	269	394	621	100	29
Faba bean	Columbo	339	35	321	48	100	100	347	401	272	132	485	346	177	76
Lupin nonbranching	Prima	340	38	268	21	100	100	416	431	174	269	309	228	179	42
Barley for feed	Otira	281	41	248	11	0	0	340	138	367	221	249	276	171	51
+ 50 kg N ha-1	Otira + N	441	31	376	24	0	0	460	289	575	268	390	471	54	27
Barley pea	Otira Agadir	448	21	443	35	67	62	475	375	496	242	498	591	72	29
Barley pea	Otira Bohatyr	416	26	397	36	66	61	468	305	478	238	412	541	82	21
Barley faba bean	Otira Columbo	423	13	372	32	53	35	387	443	440	225	422	470	94	37
Barley lupin	Otira Prima	338	30	316	21	36	35	367	248	399	246	384	320	106	36
Barley high lysine	Lysiba	206	62	244	17	0	0	338	61	222	201	259	274	247	66
+ 50 kg N ha-1	Lysiba + N	280	40	350	24	0	0	400	191	252	239	390	422	139	37
Barley*pea	Lysiba Agadir	469	19	422	38	87	66	444	492	471	220	482	565	109	44
Barley*pea	Lysiba Bohatyr	461	18	384	34	90	74	433	442	508	223	392	543	108	31
Barley*faba bean	Lysiba*Columbo	377	22	371	39	67	40	402	348	381	191	426	499	122	42
Barley*lupin	Lysiba Prima	249	34	308	30	47	37	307	235	207	195	376	354	141	51
$LSD_{0.05}$		80		60		9	11	89	123	127	67	57	74	81	21
Average year 2001		410	-	227	-	57	37	-	-	-	-	-	-	19	9
Average year 2002		329	-	394	-	65	59	-	-	-	-	-	-	203	75
Average year 2003		397	-	445	-	49	57	-	-	-	-	-	-	150	-

and protein grain yield are obtained for the same lupin genotype, which is an ideotype without branching, early ripening, and a height comparable to barley. Despite having only a minor effect on the barley yield, this ideotype has itself the second highest grain yield of all lupin ideotypes when sole cropped and a high harvest index.

The highest lupin grain yield is obtained in a wild branching ideotype. However, this ideotype results in the lowest barley yield of all intercrops. 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 t dry matter ha^{-1}. Lupin and barley made up approximately 50% each. The lupin ideotype did not affect the weed biomass. This is probably due to the low weed infestation in 2001, and the dominating effect of cereals on weed over the effect of grain legumes on the weed when grown in intercrops, as described in WP1 task 1.

Conclusion

The very restricted branching lupin ideotypes 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 less competitive ability towards weeds of lupins with restricted branching appears not to be important in intercrops with cereals, when the cereals develops normally and exert the needed weed control.

Table 3. Barley performance in intercrop with different lupin ideotypes, varying in branching structure, initial growth and height. Weed infestations in 2001 with normal crop growth and in 2002 with poor crop growth and a dominating red clover development.

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/m2 (2001)	Barley grain yield g/m2 (2001)	Lupin grain yield g/m2 (2001)	Barley seed weight mg (2001)	Weed biomass g/m2 (2001)	(2002)
LAE1	1	5	3	533	282	252	48	27	539
ROSET_E_	1	1	2	488	307	181	47	20	516
LAE32-2	1	7	3	488	303	185	48	20	506
LAE6	1	3	3	487	278	208	47	24	523
LAE2-2	1	7	5	476	350	126	49	16	541
LAP12-1	3	3	5	515	320	195	50	19	266
LAV8-4	2	5	7	446	263	182	40	17	512
LAF8-8FR	4	7	5	510	296	214	48	20	604
LAP17-1	4	5	7	377	220	156	43	22	389
LAG24	5	5	7	508	288	220	47	24	157
LAG28	7	5	7	399	199	200	44	18	154
LAW12-WS	9	5	9	427	173	254	39	18	87
LAG6	9	5	7	-	-	-	-	-	68
lsd.0.05				75	88	45	3	18	104

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

Task 1. Performance of grain legumes and cereals at low K level

Four different crops/intercrops (barley, pea/barley, faba bean and lupin) was tested at two different levels of K (0K and 80 kg K ha^{-1}) in 2001 and 2002, respectively. The average initial level of exchangeable K (K_{ex}) in the topsoil was 27 mg kg^{-1} in spring 2001 and 16 mg kg^{-1} in spring 2002. This very low K-level was achieved by K exhaustion in a grass-clover precrop.

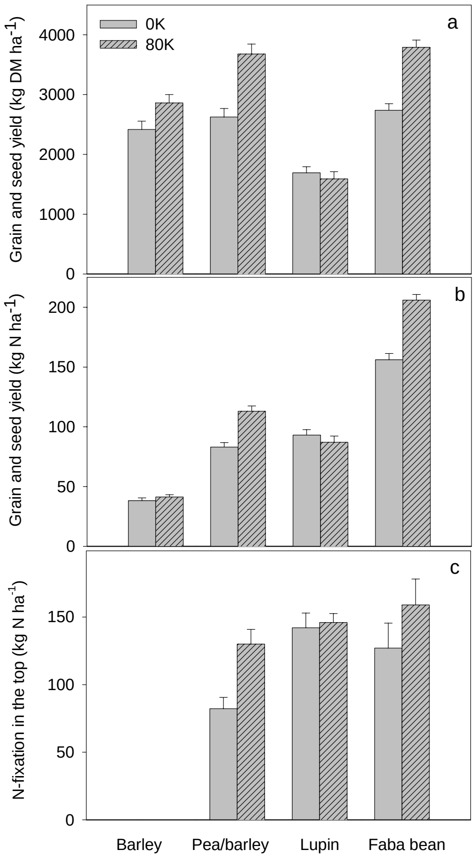

Figure 1. Dry matter (DM) yield (a) and total N (b) in harvested grain and seed of the four tested crops, and N-fixation (c) as affected by K application. Average of 2001 and 2002. Error bars: ± SE

There was significant effect of K application to barley (P>0.05), pea/barley and faba bean (P>0.001) (Fig. 1a). In the pea/barley mixture the main yield increase derived from the pea fraction. There was no effect of K application on the lupin yield. The lupins suffered from severe attack of *Botrytis cinerea* during seed filling, especially in 2001. Figure 1b shows similar effects of K application on total N harvested in grain. K application did not increase the total N content of the barley grains indicating that the K-application did not increase the translocation of N from the vegetative parts to the grains. One reason could be the low N level.

The N-fixation was estimated at the time of maximum N content in the above ground plant biomass using the "*Difference method*" with barley as the reference. The N-fixation increased by 58% (P>0.01) in the peas and by 25% (P>0.05) in the fababeans when K was applied (Figure 1c). The N-fixation in lupins did not respond to K application. Despite of approximately similar total N-fixation in pea, lupin and fababean in the 80K treatment, the total N content of the fababean seed was significantly higher than in pea and lupin. In lupin the attack of *Botrytis cinerea* was probably the main reason to this.

Despite of the lack of yield response in lupins, we observed visual differences between the K treatments in the seed filling period in 2002. The root system was less developed and on the leaves we observed brown spots in the 0K treatments. Contrary to the expectations the K deficiency seemed not to affect the quality of the harvested seed with respect to amount of free amino acids and content of selected free amino acids (see WP 5). The N content (crude protein) of the seed decreased significantly with K application in barley, peas and fababeans probably due to a dilution effect.

The precrop effects of the four crops were tested in spring barley in 2002 (following the 2001 experiment) and in 2003 (following the 2002 experiment). Despite a small difference when barley was the precrop, there were no significant differences between the two K treatments. Lupin and fababean gave significantly higher yields in the succeeding barley (1.4 t DM ha^{-1}) compared with barley and pea/barley (0.7-0.8 t DM ha^{-1}). The use of an undersown ryegrass catch crop doubled this yield level.

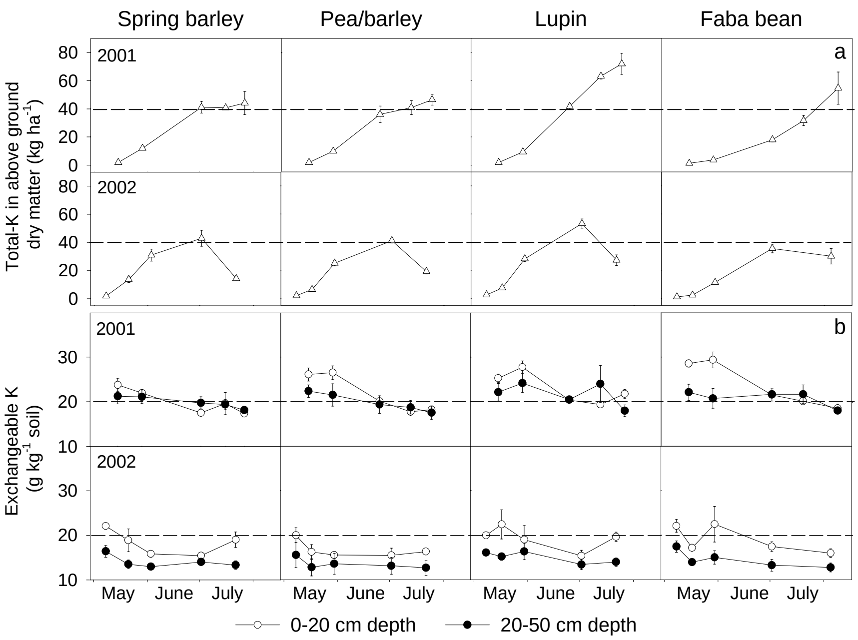

Figure 2. Total K in aboveground dry matter (kg ha^{-1}) (a) and corresponding exchangeable K (mg K kg^{-1} soil) in topsoil (0-20 cm) and subsoil (20-50 cm) (b) measured five times during the growth season in the 0K treatment. Bars: <u>+</u> SE

The total K-uptake in the above ground crop biomass differed between years and crops. In 2001 the maximum K uptake as an average of replicates was 72 kg ha^{-1} in lupines and about 45 kg ha^{-1} in barley and pea/barley (Figure 2a). Fababeans were intermediate. In 2002 this level was lower but still with the lupins taking up most K from the soil. The corresponding K_{ex} showed a drop from the first cut to the last cut in 2001, especially in the topsoil. In 2002 the initial K_{ex} level was lower and the drop in K_{ex} was less. The K_{ex} decrease in the topsoil could explain 20% of the K uptake in the lupins, 40-45% in barley and pea/barley, and 50% in the fababeans. Inclusion of the subsoil K_{ex} improved this figures to 45, 70-80 and 100%, respectively, as an average of years. The inclusion of the slowly exchangeable K fraction in the topsoil and subsoil did not improve the explanation of the K uptake. Either did measurements of pH in the topsoil and subsoil during the growth period. The pH values remained unaffected by crop growth in all four tested crops. An additional experiment with K application to barley, pea/barley, lupines and winter wheat in the "Organic crop rotation experiment" (DARCOF) confirmed the sensitivity of peas to K deficiency compared with lupines and cereals. More studies of uptake mechanisms in lupin are needed to under-stand the insensitivity to low soil K status.

Conclusions:

- Fababeans and a pea/barley intercrop responded to K application, when grown on a coarse sandy soil with low level of exchangeable K.
- Lupin (*L. angustifolius)* was unaffected by the low K level. The K uptake mechanism and the utilized soil K fractions seemed to be different in lupines compared with the other tested crops due to a) little concordance between K uptake and measured changes in the exchangeable and slowly exchangeable soil K fractions, and b) the lack of response to K application.
- K application did not affect the quality of the harvested seed with respect to amount of free amino acids and content of selected free amino acids.
- The precrop effects were significantly higher after fababeans and lupins than after barley and pea/barley. Pulse crops should always be followed by a catch crop on coarse sandy soils to protect the fixed N against leaching losses.
- In the literature it is normally assumed that the crop K-content has its maximum at the start of flowering, however the net K-uptake continued over a longer period after this point.

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 greenhouse experiments the growth of pea, fababean, and lupin (*L. angustifolius*) was tested at 3 different soil P levels, respectively 5, 15 and 45 ppm soil available P, as sole crops and in intercrops with barley in a replacement design. Soil low in P from the Højbakke experimental unit concerning long time effect of increasing application of fertilizer was mixed with sand and used in the experiment. Nine weeks after sowing the legume species showed large 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.

Fababean and pea 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 fababeans 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 fababeans. The effect of intercropping with barley was species specific for the three legumes. In intercrops the response in biomass to soil P was similar, but less significant than in pure stands. There were significantly 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 fababean 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 4). A LER value of 1.30 indicates an advantage of 30% from intercropping.

It must be noted that these results is only based on pot experiments and they cannot directly be extrapolated to practical agriculture as for example soil volume per plant is more than ten times smaller in the pots. The ranking of sensitivity of the plant species and the positive effect of growing mixtures is likely to be the same, however, the size of the response could be very different.

Conclusion

It is concluded that intercrops of grain legumes with barley appear most beneficial at low soil P level and that the response is more pronounced for peas and fababean than for lupin.

Table 4. Land Equivalent Ratio (LER) values for biomass DM and total P content in plant aerial biomass in intercrops 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. Intercropping of grain legumes and cereals on two soil types during three years.

Intercropping is defined as the growing of two or more species simultaneously on the same area of land. Intercropping often exceeds the sum of the same species grown alone on proportional areas through better use of available growth resources. Combined intercrop grain yields were comparable to grain yields of the respective sole cropped grain legume (Table 2). In descending order the greatest grain yields were obtained for intercrops containing pea, fababean and lupin, respectively. Pea dominated intercrops on both soil types with no significant difference between cultivars. Fababean dominated the intercrop on the sandy loam soil, but not on the sandy soil. Lupin was in general suppressed by barley. The barley cultivar Otira was a stronger competitor for plant growth resources compared to cv. Lysiba (Table 2). That was especially the case on the sandy loam soil, whereas cv. Lysiba was more competitive on the sandy soil probably due to weaker interspecific competition from the grain legumes.

Yield stability of intercrops were not improved compared to grain legume sole cropping (see WP1 task 2) except for the intercrops including fababean where the yield stability was increased on the sandy loam soil (Table 2). However, the yield stability for the non-fertilized barley crop used in the intercrop calculations might be unrealistically low due to the placement of this trial as a second cereal crop in the rotation (see WP1 task 2).

The intercropped grain legumes increased their proportion of plant N derived from N_2 fixation with on average 10-15% compared to the respective sole crops. Barley cv. Otira, especially, forces the grain legumes to rely on their ability to fix atmospheric N_2 to fulfill their N demand due to the high competitive ability for soil mineral N of the cultivar. As sole crops the grain legumes had all comparable nitrogen fixation per area (WP1, task2). In the intercrops the nitrogen fixation per area decreased with increasing barley suppression of the grain legume, and fixation was more reduced with Otira barley than when intercropped with cv. Lysiba and more for fababean and lupin than for peas (Table 2 and 5). Nitrogen fixation in lupin was reduced from 15 to 5-6 g N m^{-2} in intercropping (Table 5).

Despite accounting for approximately more than half of the total biomass production (Table 2) the grain legumes accumulated less soil N when intercropped than could have been expected from sole crop uptake (Table 5). At maturity the LER values for soil N uptake were all considerable higher than 1, indicating a better utilization of soil N sources by the intercrops than by sole crops. Barley was able to take up a more than proportionate share of this resource.

Table 5. Total N_2 fixation, soil N uptake and crop N balance including fixed N positioned in below-ground plant parts for each grain legume species according to Mayer et al. (2003) in sole crops and intercrops of grain legumes and cereals at a sandy loam soil (Høj); and a sandy soil (Jyn) location over 3 years.

Average of 3 years		N_2 fixation		Soil N uptake		N balance	
		Høj	Jyn	Høj	Jyn	Høj	Jyn
		g m^{-2}	g m^{-2}	g m^{-2}	g m^{-2}	g m^{-2}	g m^{-2}
Pea semi leaf-less	Agadir	14.5	20.8	6.0	7.6	1.9	2.1
Pea normal leaf	Bohatyr	13.5	21.9	5.7	7.9	2.0	2.5
Faba bean	Columbo	15	20.1	7.9	5.0	3.5	3.5
Lupin non-branching	Prima	15.1	19.4	4.1	4.7	2.7	4.4
Barley for feed	Otira	-	4.7	5.0	4.7	-3.8	-3.1
+ 50 kg N ha^{-1}	Otira + N	-	6.8	8.4	6.8	-1.4	0.1
Barley pea	Otira Agadir	9.5	16	5.1	6.2	-0.3	-0.6
Barley pea	Otira Bohatyr	8.6	15.4	5.5	7.0	-0.6	-1.2
Barley faba bean	Otira Columbo	9.2	13.9	7.9	5.4	-1.2	-0.1
Barley lupin	Otira Prima	4.9	11.2	5.6	5.9	-2.2	-1.4
Barley high ly-sine	Lysiba	-	4.7	4.5	4.7	-3.3	-3.5
+ 50 kg N ha^{-1}	Lysiba + N	-	7.9	6.5	7.9	0.4	-0.7
Barley*pea	Lysiba Agadir	12.5	16.4	5.0	6.5	0.6	-0.4
Barley*pea	Lysiba Bohatyr	13.1	16.2	4.6	6.2	1.3	0.2
Barley*faba bean	Lysiba*Columbo	14.6	15.1	5.5	5.6	2.7	0.1
Barley*lupin	Lysiba Prima	5.2	10.9	4.3	5.8	-0.8	-1.1
$LSD_{0.05}$		2.9	3.2	1.8	1.6	1.4	1.8
Average year 2001		11.4	10.4	6.9	6.4	-1.0	-0.9
Average year 2002		13.1	16.5	4.3	8.5	2.0	-1.1
Average year 2003		9.4	14.9	5.9	3.4	-0.8	2.2
$LSD_{0.05}$		1.26	1.4	0.8	0.7	0.6	0.8
Total average		11	13.8	5.7	6.1	0.1	0.04

Especially on the sandy soil an efficient use of soil N is important to avoid nitrate losses. In the intercropping situation soil N sources was efficiently exploited, while at the same time grain legume fixed N enters the plant-soil-system.

Crop N balances were established to determine the net effect on the soil N pool of growing sole crops of grain legumes and barley and of the intercrops. The balance was positive for sole cropped grain legumes, whereas it was negative for barley sole cropping (see WP1 task 2) and the intercrops (Table 5). However, when fababean was intercropped with barley cv. Lysiba a positive N balance was found. The same trend was seen for the cv. Bohatyr pea cultivar. However, grain legume-cereal intercrops are not likely to increase soil inorganic N in the long term, but rather deplete it, although at a slower rate than in barley sole cropping.

The crop residues (straw, empty pods, roots and rhizodeposits) of grain legumes are known to be richer in N than, for example, cereal residues, meaning that their decomposition and net mineralisation may proceed faster expecting to influence the yield of subsequent crops. Grain yields in the succeeding spring sown oats showed no significant differences between neither the sandy loam soil in 2002 (376 g m^{-2}) and 2003 (455 g m^{-2}) compared to the sandy soil in 2002 (395 g m^{-2}) and 2003 (420 g m^{-2}) or incorporated residues from precrops. On the sandy soil a comparison of with and without undersowing of ryegrass, as a management tool to limit nitrate leaching was included. In 2002 there was no effect of this ryegrass growth in autumn and early spring on the yield of the following oat crop, whereas significantly more dry matter was produced in succeeding oat (10%) in 2003 when undersowing ryegrass in the precrops.

Competition from barley had little effect on grain legume grain N concentration despite a general reduced grain legume total N accumulation and increased proportion of N derived from fixation. Contrary, on the sandy loam soil sole cropped barley demonstrated a significantly lower thousand grain weight compared to the intercrops indicating that intercropping with grain legumes can improve grain filling of barley. Furthermore, when barley was intercropped with pea significantly higher grain N concentration was found compared to the barley sole crops and independent of N application on both soil types. Contrary, fababean only raised cv. Otira grain N concentration on the sandy loam site whereas lupin did not influence barley grain qualities when intercropped. For further detail regarding grain quality see WP5.

Conclusion

Intercrop yields was comparable to the grain legume sole crop yields. The greatest intercrops yields were obtained in intercrops containing pea, independent of cultivar, followed by fababean, but with significantly reduced yields for lupin. There was no clear yield stability benefit comparing grain legume sole cropping and grain legume-cereal intercropping except for the intercrops including fababean reducing yield variability with 50% on the sandy loam soil. Barley cv. Otira, especially, forces the grain legumes to rely on their ability to fix atmospheric N_2 to fulfill their N demand increasing plant N derived from N_2 fixation as well as utilization of soil N. Barley cv. Lysiba leave more space for the grain legumes to develop reducing total soil N uptake but increasing nitrogen fixation per area. Barley intercropped with fababean in particular showed a high degree of complementarity for N sources. However, evaluated from crop N balances grain legume-cereal intercrops are not likely to increase soil inorganic N in the long term, but rather deplete it, although at a slower rate than in barley sole cropping. Subsequent oat was not showing any respond to precrops possibly due to nitrate losses in autumn. Finally, higher grain N concentration in intercropped barley was found compared to the barley sole crops especially when intercropped with pea. Lupin was not able to raise barley grain N concentration intercropping.

Task 2. Use of multiple resources by intercrop/weed and monocrop/weed communities
Improved competition towards weeds has been emphasized as one of the benefits of intercrops. Some authors advocate that weed suppression by intercropping is tightly coupled to intercrop yield and resource use. LER values above 1 indicate an advantage from intercropping in terms of environmental resource use. The present intercrops are utilizing environmental sources for plant growth (light, water and nutrients) more efficiently than sole crops possibly indicating stronger competitive ability towards weeds than the respective sole crops (Table 3). Since the LER for the total aboveground dry matter production were 1.12-1.53 from 12 to 53% more land would have to be used in sole cropping in order to obtain the same yield. In other words these resources could have potentially been lost to weed growth instead of crop production. Fababean-barley intercrops in particular showed high LER values, indicating that these two species differ in their use of growth resources increasing the degree of complementarity. However, there was no close relation between weed suppression and crop yield in the three years study possibly because the weed infestation on the two locations was very different at each year.

Monitoring of the use of multiple resources by intercrop-weed mixtures throughout the season could improve the mechanistic understanding of such competitive relationships. Competition between component crops for growth limiting factors like water and light is regulated by morphological and physiologically differences including soil nutrients like N (see task 1), P and K uptake when limited in supply.

The considerable differences in root systems, depth of rooting, lateral root spread and root density are factors affecting competition for water between component crops. On the sandy loam site considerable effort has been done to determine competition for soil water in pea-barley intercrops using neutron probe equipment in succeeding depths in weekly measurements throughout the season. However, it was not possibly to determine any difference in soil water content comparing intercrops and the respective sole crops in this experiment.

The amount of light absorbed by the intercrop depends on the geometry of the crop canopies, which differ for pea and barley. Thus, in 2003 specific light absorption patterns by sole and intercropped pea and barley including weeds were performed using light meter readings while removing the crops successively. The three successive harvest show that sole cropped pea absorb the same percentage of total light as sole crop barley in early growth phases followed by a later reduction caused by increased weed absorption capacity. 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 the intercrop stand. Using the FASSET simulation model this was verified using sensitivity analyses indicating the importance of vertical distribution of barley leaf area on the outcome of the interspecific competition between the barley and pea crops.

Phosphorous and K are major nutrients influencing crop yields and thereby competitive ability for utilizing other environmental growth resources. Using the same trial as for light absorption, final accumulation of P and K in pea-barley intercrop and respective sole crops was determined. Using LER for evaluating P and K productivity and efficiency per unit area of land both P and K was utilized 28% more efficient in the intercrop compared to the respective sole crop. The better use of P and K was equivalent to the improvement in N accumulation and DM production. LER can be used as an index of biological efficiency to evaluate intercrops ability to limit the access for weeds to various agronomic variables.

Conclusion

Pea and fababean-barley intercrops in particular showed high LER values indicating advantages from intercropping in terms of environmental resource use and thereby fewer resources available for weed growth. Barley and pea use water equally and competition for water was not an important factor in determining the efficiency of the present intercrop systems. Opposite, the light factor was significantly influencing the competitive relationship in the pea-barley intercrop with the barley leaf area as an important trait for the outcome of the interspecific competition between crops and weeds verified by simulation modeling and field measurements. Other growth factors determined was P and K accumulation, which was identically to N utilized around 28% more efficient in the pea-barley intercrop compared to the respective sole crops. However, further investigations are needed to clarify specific mechanisms involved in the P and K uptake.

Task 3. Effects of intercrop design and plant density on weed growth

Any part of the soil surface that is not occupied by the crop plants is potentially subject to invasion by weedy species. For sole crops the different aspects of plant populations and spatial arrangements are well understood. However, for the intercropping situation it is more complex with plant population and spatial arrangements including both total populations (all components) and component populations (each component) with different per plant pressure on certain resources comparing species.

Effects of the relative frequency of pea-barley intercrop components and of sowing density on weed development were determined. Pea showed weak competitive ability towards weeds compared to barley reflected in increasing weed biomass when reducing the crop density in sole cropping and when raising the relative frequency of pea in the intercrops (Figure 3). Increasing density introduced interspecific interactions earlier in the growth cycle indicating a potential improvement in the search of nutrient sources by 40% (LER=1.4) as compared to the sole crops.

Considerable changes in final species proportions depended mainly on the intercrop relative frequency.

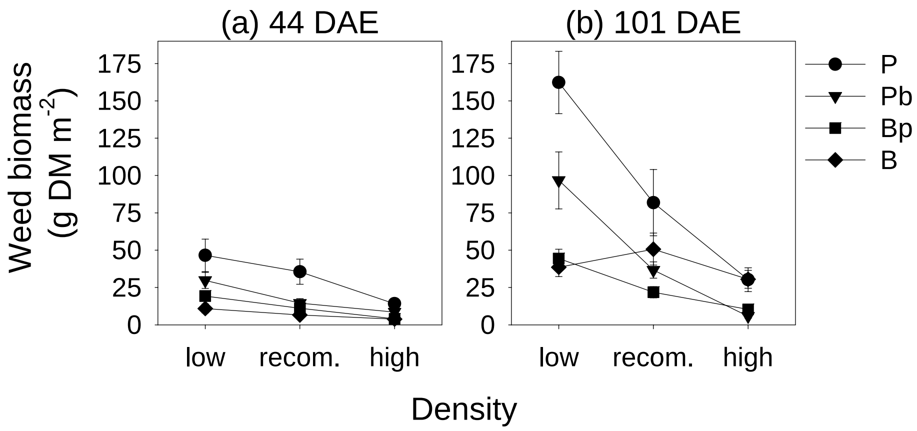

Figure 3. Total weed biomass production under pea (P) and barley (B) sole cropping and intercropping; $^2/3$pea+$^1/3$barley (Pb) and $^1/3$pea+$^2/3$barley (Bp) and when sown in low, recommended (recom.) and high densities determined 44 days after emergence (DAE) and at the final harvest (101 DAE). Values are the mean (n = 8) ± SE.

In general, two intercropping designs are commonly employed: the replacement and additive designs. The rationale for using the replacement design is that the total relative plant density of the intercrop equals the total density of the sole crop, whereas the additive design has an overall higher relative density in the intercrop than in the sole crops.

A field experiment with sole crops and intercrops of pea and spring wheat was established to study effects of intercrop design on intercropping advantages. Increasing the density of pea significantly reduced weed biomass production. The same trend was found for wheat but to less extend. In general total weed biomass production was reduced with more than 50% in sole cropped wheat compared to sole cropped pea when sowed at recommended sowing densities (Figure 4). When growing pea and wheat in intercrops instead of sole crops, there was an increased efficiency in utilizing environmental sources for plant growth and a better competitive ability towards weeds of the intercrop compared to pea. The additive design (100P100W) was reducing weed biomass production significantly compared to the replacement design (50P50W).

A density dependent response surface regression model was used to obtain information on intra- and interspecific competition in a pea-barley intercrop over a range of density combinations. Relative competitive ability of pea-barley intercrops with respect to biomass of the naturally occurring weeds showed that barley is a fourfold stronger competitor than pea against weeds after day 25 and comparable to pea after 101 days. The model clearly pointed at the critical choice of appropriate reference sole crop when using LER as an indicator of total multiple resource use. Although providing analysis of the intercrop performance over all density combinations LER fails to evaluate performance of the intercrops varying in total density.

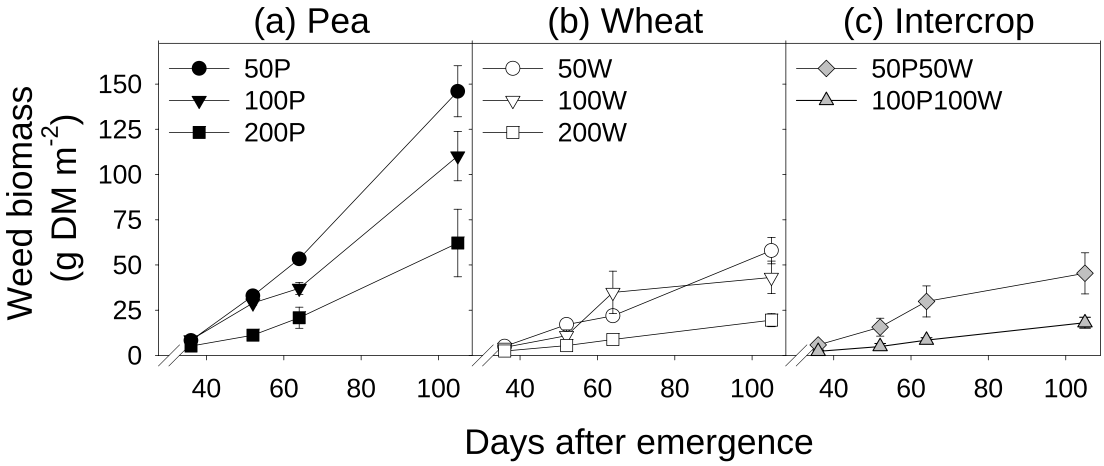

Figure 4. Weed biomass production measured throughout the growing season in pea (P) sole cropped (a), wheat (W) sole cropped (b) and dual pea-wheat mixed intercrop (c). 50 = 50% of recommended sowing density when sole cropped, 100 = 100% of recommended density when sole cropped etc. Recommended density for pea and wheat are set to 100 and 300 germinated plants m^{-2}, respectively

Conclusion

Plant population density and relative component populations (frequency) was shown to play a delicate role in the competitive relationship in intercrop systems including competitive ability towards weeds as well as targeting proportions of intercrop component yields. The use of response surface modelling to gain knowledge from more than only single intercrop combinations seems promising, but needs further investigation.

WP 4. Plant health in grain legumes and cereal crops

<u>Task 1. Effects of intercropping on plant health</u>

Our aim was to test if a barley–grain legume intercrop growing affected disease severity compared to sole cropping. The effect of barley-legume intercrop on disease levels was investigated over three years (2001-3) in two locations (Højbakkegård & Jyndevad). These two locations represent two different areas in Denmark with different soil characteristics, different exchangeable K and different total rainfall.

The range of diseases observed and their severity on the sole crop are detailed on table 6. Net blotch was the most serious disease on barley during all three years. Up to 10% Ascochyta blight was observed on pea. Chocolate spot was the most serious disease on faba bean and lupin was generally with low levels of brown spot and mould observed.

In organic farming, as disease cannot treated, any reduction in disease is can have an eventual effect of seed hygiene (for seed borne diseases) and on yield. In conventional farming it is usually recommended to spray when disease is first observed. Therefore any reduction in disease, especially early in the season will delay (and possibly avoid) the timing of spraying.

Table 6. The amount of disease observed on monocrop in percentage leaf area covered.
* length of mould lesion on lupin stem. n/o; not observed

Barley			**Pea**			**Bean**			**Lupin**		
Net blotch *(Pyrenophora teres)*			Ascochyta blight (*Mycosporella pinoides*)			Chocolate spot (*Botrytis fabea*)			Brown spot (*Peronospora*)		
2001	2002	2003	2001	2002	2003	2001	2002	2003	2001	2002	2003
25%	20%	25%	n/o	9%	10%	n/o	20%,	22%	n/o	3%	8%
Brown rust (*Puccinia hordei*)						Rust (*Uromyces viciaefabae*)			Mould (Botrytis cinerea)		
2001	2002	2003				2001	2002	2003	2001	2002	2003
18%	7%	5%				n/o	n/o	8%	n/o	n/o	0,5*cm
Powdery mildew (*Blumeria graminis* f. sp. *hordei*)											
2001	2002	2003									
1%	6%	10%									

Barley was intercropped in a two-component intercrop with pea (full leafed and semi-leafless) fababean or lupin (50:50 mixture) intercrop each of the 3 years of the project. In 2002 & 2003 in Højbakkegård, three- and four-component intercrops were also monitored.

Two-component intercrops:

A general reduction in disease was observed in all intercrop systems compared to the corresponding sole crop, see table 7. The magnitude of the reduction varied according to 1) dispersal mechanism of the diseases, 2) height of the crops and 3) anatomy of the accompanying crop e.g. full leaf pea gave larger reduction than semi-leafless pea.

Table 7. Median disease **reduction** in two-component intercrops.
*, **, *** indicates significant difference (P<0,05, 0,01, 0,001) from sole crop using the Kruskal-Wallis test. n.s. indicates no significant difference

Barley			**Pea**			**Bean**			**Lupin**		
Net blotch *(Pyrenophora teres)*			Ascochyta blight (*Mycosporella pinoides*)			Chocolate spot (*Botrytis fabea*)			Brown spot (*Peronospora*)		
2001	2002	2003	2001	2002	2003	2001	2002	2003	2001	2002	2003
÷31%*	÷33%*	÷32% **	-	÷39 %*	÷25%*	-	÷24 % ns	÷28% ns	-	÷78% ***	÷87% **
Brown rust (*Puccinia hordei*)						Rust (*Uromyces viciaefabae*)			Mould (*Botrytis cinerea*)		
2001	2002	2003				2001	2002	2003	2001	2002	2003
÷18% ns	÷28% ns	÷23% ns				-	-	÷70% ns	-	-	÷46% ns
Powdery mildew (*Blumeria graminis* f. sp. *hordei*)											
2001	2002	2003									
÷90% ns	÷19% ns	÷21% ns									

Three- and four-component intercrops:

Net Blotch and Ascochyta Blight were monitored on three and four- component intercrops. Increasing the number of components, reduced the amount of disease observed, see Fig. 5.

What does this reduction in disease mean?

It is clear that intercropping reduces disease incidence. But what is the overall affect of reduced disease? Reduction in disease on the leaves (as observed here) will have an eventual effect on disease in the seed (for seed borne diseases). Producing and maintaining disease free seed is an on-going problem in organic farming. Therefore, intercropping could be used as a method reducing disease in the organic seed pool.

Do the reductions in disease have any real effect on yield? This is a very difficult question to answer. It is fair to say, that if disease levels are high, then reduction in disease levels will have a greater effect on yield than if the initial disease levels are low. To test that, is necessary to carry out specific yield experiments, where there is a disease free control.

Otira	barley
Prima	lupin
Columbo	fababean
Bohartyr	full leafed pea
Agadir	semi-leafless pea

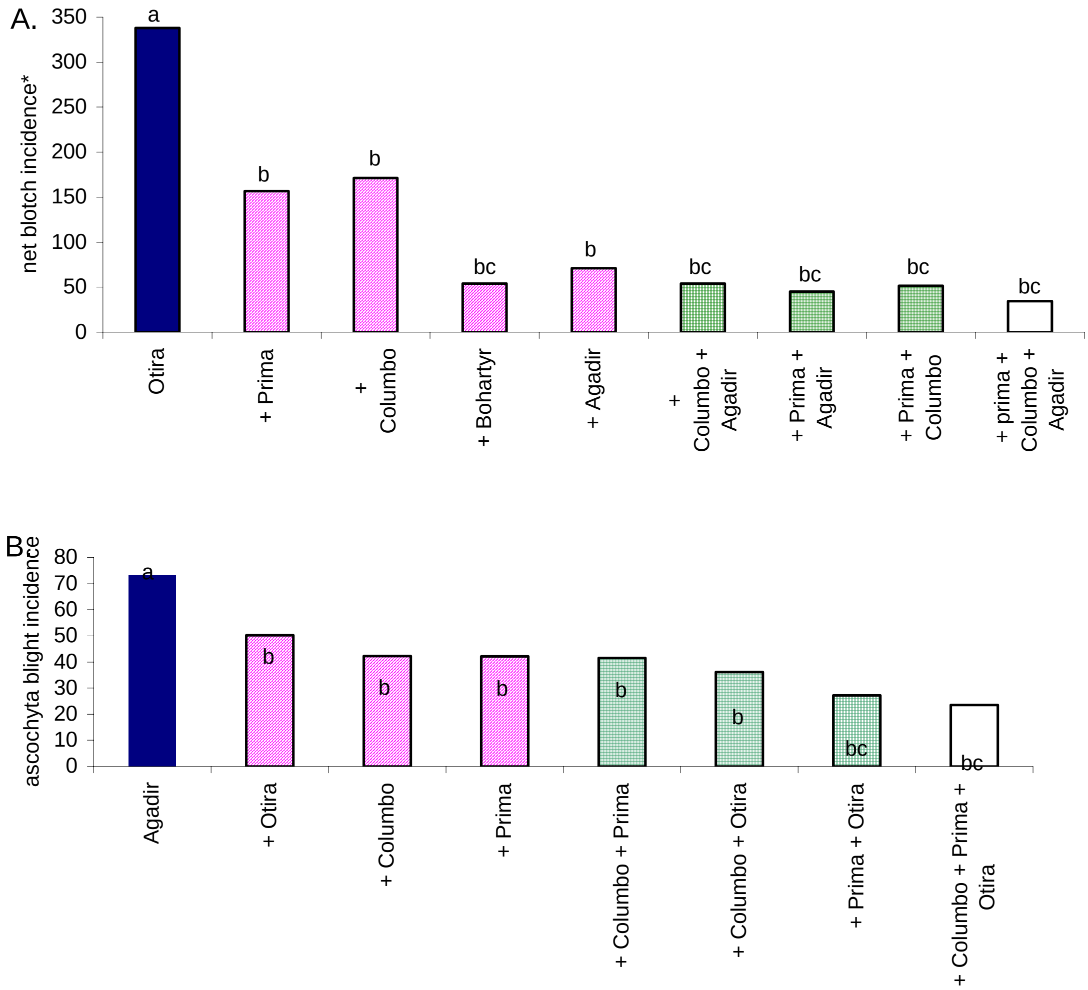

Figure 5. Effect of two-, three- and four-component intercrops on incidence of net blotch (A) and ascochyta blight (B).
* Disease incidence measured as Area Under Disease progress Curve (AUDPC)
Different letters indicate significant ($P<0.05$) differences using the Kruskal-Wallis test.

Effect of nutrients on disease in an intercrop

Nitrogen is often the most limiting factor in organic plant production. Therefore we investigated, if altering levels of N affected disease in an intercrop or affected the ‘intercrop effect’. The above sole crop and two component intercrop systems were therefore 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 the levels of mildew and rust (biotrophic fungi) and 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. This effect was exaggerated with increasing amounts of added N.

Task 2. Effects of plant nutrients on plant health

Glasshouse experiments on the effect of the availability of N, P or K on disease resistance mechanisms in barley were set up. P was included instead of Si, due to problems with controlling Si in the growth media used. 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

- 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.
- All three major nutrients (N, P & K) in isolation affected powdery mildew development, with N and K having the greatest overall effect.
- There is evidence of interactions between N and K influencing plant health.
- Barley and pea interact in the intercrop with respect to N, which in turn influences plant health.

WP5. Quality aspects and isotopic analysis

Task 1 Quality of grain and seed for feed

The nutritional quality of grains from barley (normal and high-lysine variety, respectively) and seeds from legumes (from WP1 and WP3), grown during the first two growing seasons (2001 and 2002) as sole or intercrops and at two different locations (Højbakkegaard with sandy loam and Jyndevad with coarse sandy soil), was investigated.

From each growing season 48 samples of grains and seeds were analysed for ash, crude protein, crude fat, starch, and enzyme digestible organic matter (EDOM). The mean values from protein and starch analyses are summarised in Table 8. The results demonstrate a generally pronounced positive effect of intercropping on the protein concentration in the normal variety (Otira) and high-lysine variety (Lysiba) of barley, whereas starch concentration was decreased.

No effect of intercropping on the chemical analyses could be seen for the legumes in the first growing season. Therefore, the results are given only as the mean according to location for each legume in 2001. However, for the second growing season, a slightly increase was seen for starch in most cases in the intercropped legumes. Intercropping had none, or very small, effect on analysis results of crude fat, ash, and EDOM in barley and legumes. Consequently, intercropping had no pronounced influence on the energy value of either barley or the grain legumes.

Table 8. Effect of intercropping, year, and location on protein and starch (% of DM) in barley and legumes

a. Protein

		Højbakkegaard				Jyndevad			
		2001		2002		2001		2002	
Crop	Variety	Sole	Inter	Sole	Inter	Sole	Inter	Sole	Inter
Barley	Otira	10.0	12.1	7.6	9.6	10.0	10.4	8.3	10.0
Barley	Lysiba	12.0	15.2	10.5	10.9	10.4	11.8	9.6	12.9
		Sole/intercrop				Sole /intercrop			
Pea	Bohatyr	23.4		19.3	19.5	31.0		23.2	23.0
Pea	Agadir	21.5		19.4	19.3	29.0		20.6	22.4
Faba	Columbo	28.8		27.8	28.2	35.0		29.1	29.5
Lupin	Prima	34.1		27.1	28.1	34.9		27.7	27.4

b. Starch

		Højbakkegaard				Jyndevad			
		2001		2002		2001		2002	
Crop	Variety	Sole	Inter	Sole	Inter	Sole	Inter	Sole	Inter
Barley	Otira	59.1	56.5	60.1	58.6	54.6	55.6	56.6	53.8
Barley	Lysiba	53.4	50.3	53.6	51.7	54.1	52.6	56.9	49.2
		Sole/intercrop				Sole/intercrop			
Pea	Bohatyr	43.1		45.4	46.7	36.6		47.1	47.7
Pea	Agadir	44.9		47.4	47.4	35.8		46.9	47.3
Faba	Columbo	35.6		34.7	36.5	29.5		38.1	40.0
Lupin	Prima	0.6		0.2	0.2	0.2		0.3	0.2

The results demonstrated 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. 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 cultivar. Starch content in barley was, generally, lower in barley kernels from intercropping. Crude fat concentration was also slightly lower in barley from intercropping. However, a rather high variation in crude fat was observed (2.1 to 3.7% in the normal variety and 3.6 to 5.5% in the high lysine variety).

During the first growing season a considerable variation in the protein content within the same cultivars, except for lupin, was found (Table 8). This was mainly due to a rather wet and cold weather, which delayed the sowing at Jyndevad and resulted in rather poor crop growth and seed yield which may explain the general high protein concentration in the legume seeds.

Protein is, generally, the limiting factor in animal feeds grown in Denmark (and Europe). Furthermore, the nutritional quality of grains and seeds is, generally, mainly reflected by variations in the protein concentration.

Therefore, selected samples according to high and low protein contents, respectively, from barley (Otira and Lysiba), pea (Bohatyr and Agadir) and fababean (Columbo) from the first growing season were further investigated for the effect of protein level on other relevant nutritional qualities, including compositions of dietary fibre and amino acids, anti-nutritional factors, and direct biological investigations using a standard rat assay as a model (Table 9).

Main results from these investigations were that higher protein content was accompanied by reduced starch but no changes in the crude fat content, fibre composition, and anti-nutritional compounds (tannins and trypsin inhibitors) were observed. Furthermore, the biological investigations demonstrated generally higher protein digestibility and, in the barley cultivars, also a higher dry matter digestibility in samples with higher protein concentration. The *in vivo* dry matter digestibility corresponded closely to the enzymatic *in vitro* digestibility of organic matter.

The effect on the nutritional quality of barley grains and legume seeds was also investigated in a study at Jyndevad, where a very low potassium (K) level was achieved by K exhaustion in a grass-clover pre-crop. The effect of potassium fertilisation (80 kg K per ha) on crop yield was studied in WP 2.

Table 9. Nutritional quality of crop samples with low and high protein in the seeds

	Barley				Pea				Faba bean	
	Otira		Lysiba		Bohatyr		Agadir		Columbo	
Protein content	low	high	Low	high	low	high	low	high	low	high
Intercropped	-	+	-	+	-	-	-	+	-	+
Location	Jyn	Høj	Jyn	Høj	Høj	Høj	Høj	Jyn	Høj	Jyn
Chemical composition (% of dry matter):										
Ash	2.3	2.7	2.4	2.5	3.0	2,8	3.0	2.7	3.8	4.1
Crude protein	9.0	14.6	10.2	15.8	21.9	31.4	20.7	30.7	28.9	36.0
Crude fat	3.4	3.6	4.5	4.9	2.6	2.5	2.7	2.5	2.7	2.5
Starch	56.3	55.3	55.0	48.6	43.2	36.7	44.5	35.8	36.2	29.5
Soluble NSP[1]	5.1	5.3	3.4	2.7	5.0	4.9	4.6	4.7	6.0	4.0
Insoluble NSP	14.9	11.8	15.7	16.5	13.4	15.3	14.0	13.7	16.2	16.1
Lignin	4.0	4.6	3.0	3.6	0.8	0.5	0.8	1.3	1.1	0.9
Total dietary fibre	24.0	21.7	22.1	22.8	19.2	20.7	19.4	19.7	23.3	21.0
EDOM[2]	81.7	83.6	82.1	82.9	85.1	91.1	87.4	90.6	89.2	90.5
Amino acids (first limiting) g per16g N:										
Lysine	4.0	3.4	5.1	4.7	7.2	6.5	7.1	6.6	6.2	5.7
Threonine	3.6	3.1	4.1	3.8	3.6	3.4	3.7	3.5	3.3	3.2
Methionine	1.8	1.5	2.0	1.8	0.9	0.8	1.0	0.9	0.7	0.7
Cystine	2.5	2.0	2.5	2.1	1.5	1.3	1.5	1.4	1.2	1.1
ANF's										
Tannin	0.38	0.32	0.40	0.38	0.45	0.47	0.42	0.46	0.65	0.75
Trypsin inhibitor[3]	0.27	0.28	0.19	0.19	0.49	0.49	0.30	0.32	0.49	0.49
Biological analyses (%):										
TD[4]	84.9	90.8	86.9	92.2	93.7	95.4	96.0	97.0	95.2	95.7
BV[5]	82.8	75.7	89.3	85.2	85.2	77.1	90.8	84.8	80.7	77.3
NPU[6]	70.3	68.9	77.6	78.5	79.9	73.5	87.1	82.2	76.8	74.0
DMD[7]	78.1	81.6	80.8	83.0	88.5	91.0	89.5	91.2	88.4	87.8

[1]Non-starch polysaccharides; [2]Enzyme digestibility (%) of organic matter; [3]mg trypsin inhibited per g dry matter; [4]True digestibility of protein; [5]Biological value; [6]Net protein utilisation; [7]Dry matter digestibility

The composition of protein and starch in samples collected during the study during two years (2001 and 2002) are given in Table 10. Also in this experiment a considerable improvement in the protein concentration in barley kernels was found when intercropped with pea. Fertilisation with K had in general only little influence on the nutritional value in sole crops. However, intercropped pea and barley were generally lower in protein and higher in starch after K fertilisation.

This study included also preliminary analyses relating to the protein synthesis, which is supposed to be depressed during potassium undersupply to the crops. Thus, the samples from the first growing season were tentatively analysed for free amino acids and the second year for soluble protein in order to find a suitable parameter for studying this. However, the results from these analyses were not consistent and more investigations and development of the method is needed for these investigations.

Conclusions

The main effect on the nutritional quality of crops from intercropping of barley and legumes was found to be a generally higher protein concentration in the barley grains but no systematic effect was found for legume seeds. In general, the biological value of the protein is reduced when the protein concentration is increased. This is also the case for the net protein utilisation (NPU), except for the high-lysine barley (Lysiba). The higher protein concentration in barley and legumes also improved the protein digestibility.

Table 10. Effect of potassium (K) on the nutritional quality of barley grains and legume seeds

Crop:	K	Starch		Protein		Glu + Gln[1]	Soluble N[2]
	Kg per ha	2001	2002	2001	2002	2001	2002
Barley	0	60,7	54,2	9,2	10,0	10,1	32
	80	60,9	54,3	9,0	10,9	10,8	37
Faba bean	0	32,7	31,2	35,7	36,0	6,0	85
	80	33,6	34,2	34,9	35,2	5,9	85
Lupin	0	0,4	0	35,0	34,7	8,9	88
	80	0,3	0	36,5	33,1	8,3	86
Pea[3]	0	40,5	40,2	28,5	28,3	9,8	85
	80	41,9	42,6	25,2	24,8	13,9	85
Barley[3]	0	55,6	48,4	14,8	13,4	7,5	31
	80	57,0	51,2	13,0	13,0	8,7	30

[1]Free amino acids: glutamic acid + glutamine (g per kg crude protein); [2]Soluble protein (percent of total protein); [3]Samples from intercropping of pea and barley - other samples are sole cropped.
All values are mean of two different samples

Potassium depletion did not influence the nutritive quality in sole crops, but increased the concentration of protein and reduced the concentration of starch, respectively, in intercropped pea and barley.

Task 2. Baking quality of wheat

At present, considerably amounts of organically grown bread wheat is imported, despite the fact that we might be able to improve the wheat baking qualities changing our traditional cropping strategies. Intercropping as compared to sole cropping is one option.

The object of this preliminary investigation utilising ongoing GENESIS field activities was to evaluate the bread-making quality of wheat as influenced by intercropping compared to sole cropping with or without N application including the effect of either pea or fababean as companion crop. The field experiments were conducted at Højbakkegård (see WP1 task2) in 2003 in a wheat-fababean trial with a 5 g urea-N m^{-2} treatment and different intercrop proportions of wheat and pea in a neighbouring trial. Bread-making quality was determined using NIT techniques at DIAS Flakkebjerg in collaboration with scientist Johannes Ravn Jørgensen.

Intercropping wheat with fababean or pea significantly increased the protein percentage compared to the respective sole crop independent of N application (Figure 6). Applying nitrogen significantly increased the grain protein percentage, especially in the wheat sole cropping situation. Intercropped pea increased the wheat grain protein concentration significantly more than intercropped fababean. Using elemental analysis for grain nitrogen determinations it was concluded that protein assessments from NIT technology was satisfactory (r^2=0.89). When correlating protein concentration with other parameters such as volume weight (Figure 6) or kernel size distribution no significant decrease in these physical quality parameters was found. As expected gluten raised linearly with increasing protein concentration (r^2=0.80) whereas starch opposite decreased linearly (r^2=0.88). Thus, negative effects of increasing protein concentrations were not found for either fababean or pea as companion crop.

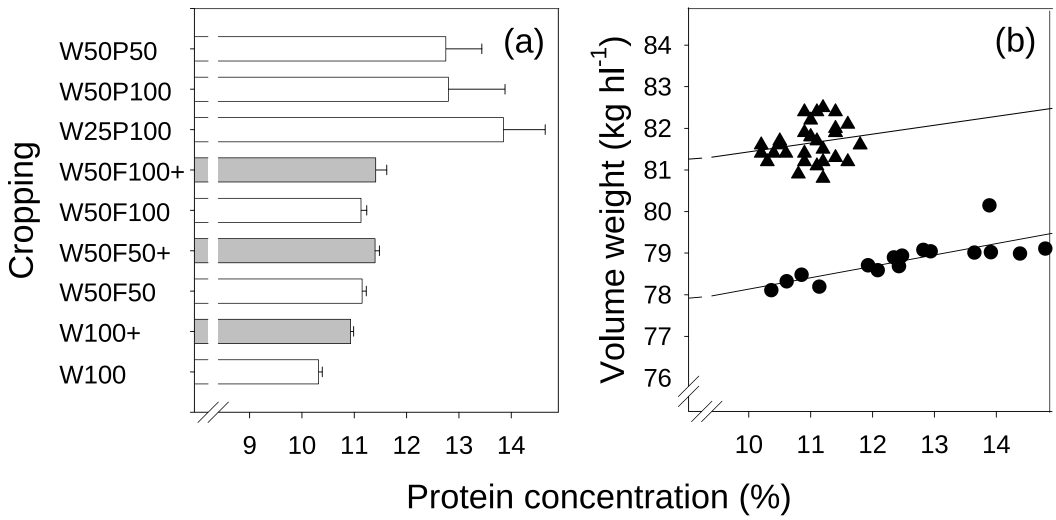

Figure 6 . Wheat (W) protein concentration (a) and wheat protein concentration as a function of volume weight when intercropped with faba bean (F) or pea (P) (b). In figure a the sown proportions of wheat and grain legumes are indicated by a letter for the species and a number; 25 = 25% of recommended sowing density when sole cropped, 50 = 50% of recommended density when sole cropped etc. Recommended density for wheat, fababean and pea are set to 300, 40 and 90 germinated plants m^{-2}. In the same figure a + on the y-axis indicate application of 5 g urea-N m^{-2}.

Conclusion

Protein content of wheat for bread making is a key parameter for quality assessments on the market. When intercropping wheat with fababean or pea the grain protein concentration is increased significantly compared to sole cropped wheat, in particular with pea as companion crop. The competition for other growth factors than N (light, water, P, etc.) results in enhanced grain N concentration. There seems to be no negative effect on other bread-making quality parameters when raising the protein concentration using present NIT technology. However, before being able to fully evaluate intercropping, as a cropping strategy for wheat production for bread real physical baking test needs to be done.

Task 3. Isotopic analysis

Risø carried out a comprehensive analytical programme in relation to determination of total N and stable N isotope composition of samples from WP1 and WP3.

Perspectives and new projects generated

The obtained results have as already had large impact in practical agriculture and on initiation of new research programmes. The project results have effectively been disseminated to practical farming via Landscentret, Økologisk Landsforening and at presentations at field days, workshops, meetings and in papers. It is noted that the total organic area with intercropped grain legumes to maturity has more than doubled from 2000-01 to 2002-03. Many farmers have obtained an understanding of the possibilities in intercropping and are practicing the system. DLG has started a production of bread wheat based on mixtures of grain legumes and wheat and have build up facilities to separate the harvested mixtures. Similarly there is also interest from seed companies in production of healthier pea seeds from intercropping with cereals.

The best yields in intercrops do not compare favourable to the best yield of grain legume in sole crops. However, growing high proportion grain legume sole crops in organic rotations is not an option in practical farming, due to accelerating weed infestations and soil borne diseases such as *Fusarium* and *Aphanomyces*. Therefore it is more relevant to compare the intercrops to yields of cereals in pure stands, which is in favour of the intercrops due to the low cereal yields in organic farming. Growing a high proportion of intercrops of cereals and grain legumes as demonstrated in the present project would have a reducing effects on a number of plant leaf diseases and improve grain quality and it would not cause significant weed problems compared to cereal sole cropping. This leaves the major agronomic problem for the mixtures to be related to rotational diseases. Thus the grain and particular the protein grain production could be significantly improved in organic farming if intercrops of cereals and grain legumes could replace cereals sole crops. This requires further research in rotational diseases and resistance breeding which is actually initiated in The FØJO2 Grainleg programme.

Since the initiation of the this project an EU project on intercropping grain legumes and cereals in organic agriculture has also been initiated and now running in its second year (www.intercrop.dk). A new project in the EU 6th Frameworkprogramme with Risø as participant also involves intercropping in organic farming systems. Here three European partners study in more detail the mechanisms of disease reduction in intercrop of grain legumes and cereals in low input farming systems.

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C.2 Fulfillment of deliverables and milestones

WP 1 Evaluation of potential of grain legumes for mono- and intercropping with cereals	**Time schedule according to application**	**Deviations, if any***
Task		
1. Screening of potential genotypes	2000-2001	OK
2. Production, yield variability, nitrogen fixation and quality of grain legumes on two soil types	2001-2003	OK
3. Ideotypes for intercropping	2001-2002	OK
Deliverables		
D1. 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	OK
D2 Genotypic characteristics for good intercropping and weed suppressing ability.	2003	OK
D3. Paper on yield variability and N_2 fixation in grain legumes on two soil types	2003	*1) December 2004
D4. Paper on grain legume genotypes for intercropping and weed suppression	2002	OK
Milestones		
1. Background for selecting genotypes for the experiments in work package 2, 3 and 4.	2001	OK
2. Recommendations for species and varieties for inter- and mono-cropping .	2003	OK
3. Recommendations for ideo-types of narrow-leaf lupin for intercropping or weed management.	2003	OK
WP2 Performance of grain legumes and cereals at low and low P and K levels	**Time schedule according to application**	**Deviations, if any***
Task		
1.Determination of the effect of low K-status on the production of protein in cereal and grain legume crops on a coarse sandy soil.	2001-2003	OK
2. Comparison on the crop performance and P uptake at low levels of P	2001-2003	OK
Deliverables		
D5. Paper on the effect of low K-status on protein production on a coarse sandy soil submitted to international refereed journal.	2003	*2) -
D6. 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	*2) December 2004
D7. Papers in national agronomic magazines for information about the results.	2003	*3) December 2004
D8. Paper on P uptake of grain legumes and cereals at low P status soil and their growth performance	2003	*4)
Milestones		
1.The effect of low K-status and K-fertilisation on protein production in different cereal and grain legume crops on coarse sandy soil has been clarified.	2003	Done
2. Field experiments finished.	2003	Done
3. The pre crop effect of different cereal and grain legume crops on coarse sandy soil has been clarified.	2003	Done
4. Characterisation of P uptake capacity of grain legumes and their growth performance at low P status soil	2003	*4)
5. Recommendation for species/genotype choice at low P status soil	2003	*4)

WP3 Intercropping grain legumes and cereals – Resource use, weed management and seed quality	Time schedule according to application	Deviations, if any*
Task		
1 Intercropping of grain legumes and cereals on two soil types during three years.	2001-2003	OK
2 Use of multiple resources by intercrop/weed and monocrop/weed communities	2001-2003	OK
3 Effects of intercrop design and plant density on weed growth	2001-2003	OK
Deliverables		
D9 Paper on the effects of intercropping grain legumes and cereals at different soil types on various parameters	ultimo. 2003	Ultimo 04 See appendix
D10 Paper on multiple resource use by inter- and monocrop of pea and barley	ultimo. 2003	Medio 05 See appendix
D11 Paper on the competition for multiple resources between intercrops and weeds	ultimo. 2003	Ultimo 04 See appendix
D12 Paper on the effect of intercrop design and plant density on the competition with weeds	ultimo. 2003	Ultimo 04 See appendix
D13 Guidelines for intercropping grain legumes and cereals for multiple functions in organic cropping systems	ultimo. 2003	Ultimo 04 See appendix
Milestones		
1 Results from field experiments year 1	ultimo. 2001	OK
2 Results from field experiments year 2	ultimo. 2002	OK
3 Results from field experiments year 3, report and papers etc.	ultimo. 2003	OK
WP4 Disease resistance in relation to intercropping and nutrient uptake	**Time schedule according to application**	**Deviations, if any***
Task		
1 Evaluate effects of growing barley and pea as intercrop on diseases in the field. The following model system will be used: barley attacked by barley powdery mildew (*Blumeria graminis* f.sp. *hordei*) and pea attacked by *Mycosphaerella pinodes*, one of the three phytopathogenic fungi causing *Ascochyta* blight on pea.	01/2001-08/2002	OK
2 Characterise possible influence of intercropping on disease resistance mechanisms in individual host plants (barley / *B. graminis* and pea / *M. pinodes*) due to changes in nutritional balance/status in the plants.	05/2002-05/2003	OK
3 Evaluate possible disease problems related to nutrient uptake on sandy soils low in K and characterise possible influence on disease resistance mechanisms in individual host plants (barley / *B. graminis* and pea / *M. pinodes*).	04/2001-07/2003	OK
4 Monitoring diseases in field plots described in WP2 and WP3.	04/2001-07/2003	OK
Deliverables		
D14.Paper about intercropping and disease resistance	2002	OK
D15.Paper about influence of nutrient uptake on disease resistance	2003	Sept 2004
D16. Recommendations of plant characteristics which should be taken into consideration when choosing cultivar or breeding material	2003	With WP1 and WP3 in farmers booklet?
Milestones		
1 Paper about intercropping and disease resistance (December 2002)	2002	yes
2 Paper about influence of nutrient uptake on disease resistance (May 2003)	2003	Sept 2004
WP5 Quality of grain legumes and cereals and isotopic analysis	**Time schedule according to application**	**Deviations, if any***
Task		

1 Determination of the effect of cultivation system on nutritional quality of grain legumes	2002-2003	OK
2 Determination of impact of type of soil and K status of soil on nutritional quality of grain legumes	2002-2003	OK
3. Identification of possible antinutritional factors in grain legumes	2002-2003	OK
4. Quality of wheat for bread	2003	OK
5. Staple isotopes	2002-2003	OK
Deliverables		
D17 Report on the variation in total nitrogen from the screening study	Dec 2003	OK
D18 Paper on the effect of cultivation system on the nutritional quality of grain legumes	Dec 2003	5) September 2004
D19 Paper on the impact of type of soil and its K status of soil on the nutritional quality of grain legumes	Dec 2003	6)
D20 Identification of possible antinutritional factors in peas and fababeans	Dec 2003	7)
D21Stable isotope ratios determined for WP1, WP2, WP3	Jan 2002 Jan 2003 Dec 2003	OK OK OK
Milestones		
Evaluation of variation in total nitrogen from the screening study	2002	OK
Evaluation of impact of cultivation system on the nutritional quality of grain legumes	2003	OK
Evaluation of impact of type of soil and its K-status on the nutritional quality of grain legumes	2003	OK
Identification of possible antinutritional factors in grain legumes grown under organic farming conditions	2003	OK
Evaluation of baking quality of wheat	2003	OK
Stable isotope ratios determined for WP1, WP2, and WP3	2002, 2003	OK, OK

1) The paper is under preparation and will be submitted in December 2004. The final results had been delayed due to verification of chemical analyses.
2) The two papers 1 and 2 will be merged into one paper: “Protein production at low K status on a coarse sandy soil”. The lack of effects in the quality investigations makes it more appropriate to do this. The paper will be submittet December 2004.
3) One national congress paper has been written Januar 2004, and one more national paper will be submitted December 2004.
4) See descriptions of deviations WP2.
5) A final manuscript is under preparation and planned to be finished for submission for a scientific journal in September.
6) The results from this study are too limited for an individual paper and will be included in either D5 or D18.
7) Due to initial analytical problems and also to the changed strategy the results from these studies were very limited and will be published together with D18.

D. Description of deviations and subsequent adjustments of plans

WP2. Task 1

The deliverables 1-3, WP2, has been postponed due to work on a Ph.d. project "Management of potassium in low-input systems", which was defended in November 2003.

WP2. Task 2

The planned field trials were destroyed by birds and replaced by greenhouse pot experiments. The original field trials were planed to be located at Højbakkegård experimental unit concerning long time effect of increasing application of N, P and K in two years. The permanent design includes seven combinations of fertilizer level repeated two times. 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, fababean and lupin were established. Despite the installation of three bird scare alarms the first year and covering by elastic nets lifted above the crop the second year birds in large numbers were able to press the net to the ground and pick up the plants through the nets. The legumes were eaten and consequently the field experiments abandoned both years. Within the given budget it was not possibly to grow grain legumes in this long term experimental area because it covers a field of more than 300 m length and because the area is under heavy bird damage pressure. In agreement with the DARCOF management the field experiments were replaced by greenhouse pot experiments. Three experiments were started, however, only 1 was successfully carried through to harvest of the plants. The main difficulty was establishment of the plants with a good growth. Despite pre-germination in petri-dishes sowing of double density and irrigation by a wick system to avoid water logging, too many plant "damped of" during emergence. Resowing where plants were missing was done, but after some time size difference was too large. The same soil could not be used again because the plants had already taken up P from the soil.

The characterization of the grain legume species with respect to their tolerance to low soil P and their behaviour in mixture with cereals at low P levels in this work package is based solely on greenhouse pod experiments instead of the abandoned field experiments. Thus the results cannot be extrapolated to field conditions due to differences growth conditions e.g. in soil volumes. It is also not likely that the results have a quality to be published in an international scientific journal.

WP3

The deadlines for all deliverables were extended due to the provided project prolongation. Deliverable 11 dealing with use of multiple resources between intercrops and weeds was not fully completed. We were not capable to measure especially light, P and K for more than one year (1 year light measurements was cancelled due to experimental errors), which is not regarded as sufficient for publication in an international reviewed journal. However, the semi-field pot experiment conducted in 2001 will be included in a KVL funded PhD project work including water balance calculations together with ^{15}N, P and K analysis. This work was originally planned to finalize ultimo 2003 but it was extended due to a maternity leave.

WP4

In the original GENESIS application, our objective was to look at the effect of the nutrients nitrogen, potassium and silicon on disease resistance mechanisms. However the substrates in which the plants were grown; vermiculite or sand; contained silicon and therefore it was impossible to control levels of silicon. Therefore we worked with phosphorous instead of silicon.

WP5

The analytical scheme has been changed from that given in the proposal in order to allow a more detailed study on the basic chemical analyses (ash, crude protein, crude fat, starch and EDOM), which are the general basis for common feed analyses.Thus, the thirty complete chemical analyses including analyses of amino acids and ANF´s were replaced by 1) 96 basic chemical analyses and, 2) 10 complete analyses, including amino acids, fibre fractions, and ANF´s, 3) 40 analyses of protein and starch, and 4) 40 specific analyses for investigating protein synthesis in potassium deficient crops. Due to a delay in some of the specific analyses, papers on the nutritive quality are not finished yet.

Project publications and other products

Copy from Organic Eprints

Affiliation (by peer review status): I. 5 (GENESIS) Production of grain legumes and cereals for animal feed Country / Organization / Project (1891) Denmark (728) DARCOF II (2000-2005) (607) **I. 5 (GENESIS) Production of grain legumes and cereals for animal feed (51)**

Number of eprints: **68**.

Peer-reviewed and accepted

English

Andersen, Mette Klindt; Hauggaard-Nielsen, Henrik; Ambus, Per and Jensen, Erik Steen (2004) Biomass production, symbiotic nitrogen fixation and inorganic N use in dual and tri-component annual intercrops. *Plant and Soil*.**

Bellostas, Natalia; Hauggaard-Nielsen, Henrik; Andersen, Mette Klindt and Jensen, Erik Steen (2003) Early interference dynamics in intercrops of pea, barley and oilseed rape. *Biological Agriculture and Horticulture*.*

Berntsen, J.; Hauggaard-Nielsen, H.; Olesen, J.E.; Petersen, B.M.; Jensen, E.S. and Thomsen, A. (2004) Modelling dry matter production and resource use in intercrops of pea and barley. *Field Crops Research* 88(1):pp. 69-83.**

de Neergaard, Andreas; Hauggaard-Nielsen, Henrik; Jensen, Lars Stoumann and Magid, Jakob (2002) Decomposition of white clover (Trifolium repens) and ryegrass (Lolium perenne) components: C and N dynamics simulated with the DAISY soil organic matter submodel. *European Journal of Agronomy* 16(1):pp. 43-55.**

de Neergaard, Andreas; Hauggaard-Nielsen, Henrik; Jensen, Lars Stoumann and Magid, Jakob (2002) Decomposition of white clover (Trifolium repens) and ryegrass (Lolium perenne) components: C and N dynamics simulated with the DAISY soil organic matter submodel . *European Journal of Agronomy*(16):pp. 43-55.**

Hauggaard-Nielsen, Henrik; Ambus, Per and Jensen, Erik Steen (2003) The comparison of nitrogen use and leaching in sole cropped versus intercropped pea and barley. *Nutrient Cycling in Agroecosystems* 65(3):pp. 289-300.**

Hauggaard-Nielsen, Henrik; Ambus, Per and Jensen, Erik Steen (2001) Interspecific competition, N use and interference with weeds in pea-barley intercropping. *Field Crops Research* 70(2):pp. 101-109.**

Hauggaard-Nielsen, Henrik; Ambus, Per and Jensen, Erik Steen (2001) Temporal and spatial root distribution and competition for nitrogen in pea-barley intercropping – a field study employing 32P methodology. *Plant and Soil* 236(1):pp. 63-74.**

Hauggaard-Nielsen, Henrik and Jensen, Erik Steen (2004) Facilitative root interactions in intercrops. *Plant and Soil*.*

Hauggaard-Nielsen, Henrik and Jensen, Erik Steen (2001) Evaluating pea and barley cultivars for complementarity in intercropping at different levels of soil N availability. *Field Crops Research* 72(3):pp. 185-196.**

Jensen, Erik Steen and Hauggaard-Nielsen, Henrik (2002) Understanding the role of grain legumes in the N cycling of agroecosystems. In *Grain Legumes*, Volume 36, No 2, page pp. 12-14. AEP.

Jensen, Dr. Erik Steen and Hauggaard-Nielsen, Dr. Henrik (2003) How can increased use of biological N2 fixation in agriculture benefit the environment?. *Plant and Soil*(252):pp. 177-186.**

Joernsgaard, B.; Christiansen, J.L. and Kuptsov, N. (2003) Adaptation of lupins for Northern European maritime conditions. Paper presented at The 10' international lupin conference, Island, 19-24 June 2002; To be published in *Proceedings of the 10' international lupin conference*.**

Joernsgaard, B.; Raza, S.; Jensen, E.S. and Christiansen, J.L. (2001) Choise of species and varieties for grain legumesand cereals for inter- and monocropping in organic agricultural systems. Paper presented at The 4'th AEP conference, Cracow, Poland, July 2001; Published in *Proceedings of the 4'th AEP conference*.

Kinane, Dr. J. and Lyngkjær, Dr. M. (2003) Effect of Barley-Legume Intercrop and Major Nutrients on Disease Frequency in an Organic Farming System. Paper presented at (International Congress for Plant Pathology). 8th International Congress for Plant Pathology, Christchurch, New Zealand., 2-7th February 2003.

Kinane, Dr. J. and Lyngkjær, Dr. M. (2002) Effect of Barley-Legume Intercrop and Major Nutrients on Disease Frequency in an Organic Farming System. Paper presented at EFPP (European Foundation for Plant pathology) 2002: Disease Resistance in Plant Pathology., Prague, Czech Republic., 9-14 September 2002.

Knudsen, Marie Trydeman; Hauggaard-Nielsen, Henrik; Joernsgaard, Bjarne and Jensen, Erik Steen (2004) Comparison of interspecific competition and N use in pea–barley, faba bean–barley and lupin–barley intercrops grown at two temperate locations. *Journal of Agricultural Science*.

Danish

Kristensen, Lars; Østergård, Hanne and Jørnsgård, Bjarne (2001) Forædlingsmål og forædlingsopgaver i økologisk korn og bælgsæd [Breeding objectives and breeding activities in organic cereals and grainlegumes], in Nielsen, Bent and Kristensen, Lars, Eds. *Forædling af korn og bælgsæd samt produktion af såsæd i økologisk Jordbrug.*. FØJO-rapport no. 15/2001, chapter 8, page pp. 109-137. DIAS.**

Kristensen, Lars; Østergård, Hanne and Jørnsgård, Bjarne (2001) Sortsafprøvning i korn og bælgsæd i økologisk jordbrug [Variety testing in cereals and grain legumes in organic farming], in Nielsen, Bent and Kristensen, Lars, Eds. *Forædling af korn og bælgsæd samt produktion af såsæd i økologisk Jordbrug*. FØJO-rapport no. 15/2001, chapter 9, page pp. 141-161. Forskningscenter for Økologisk Jordbrug.**

Submitted for peer-review but not yet accepted

English

Hauggaard-Nielsen, Henrik; Andersen, Mette Klindt; Joernsgaard, Bjarne and Jensen, Erik Steen (2005) Density and relative frequency effects on competitive interactions and resource use in pea-barley intercrops. *Field Crops Research*.

Hauggaard-Nielsen, Henrik and Nikolajsen, Jakob Tranberg (2005) Intercropping with cereals for weed management in grain legumes. *Weed Research*.

Not peer-reviewed

English

Carrouee, Benoir; Ellis, Noel; Jensen, Erik Steen and Schneider, Anne (2002) The benefits of grain legumes for an environment-friendly and sustainable European agriculture. In *Grain legumes*, No 36, page pp. 21-23. AEP- European association of grain legume research.**

Hauggaard-Nielsen, H.; Jensen, E.S.; Aveline, A. and Crozat, Y. (2004) Grain legumes and nitrate leaching: significance and prevention. [oral] Presentation at *Legumes for the benefit of agriculture, nutrition and the environment*, Palais de Congrès, Dijon, France, 7 -11 June 2004.**

Hauggaard-Nielsen, Henrik (2002) Grain legumes in organic cropping systems. [oral] Presentation at *Grain Legumes for Sustainable Agriculture*, Strasbourg, France, 26-28 September 2002.

Hauggaard-Nielsen, Henrik; Ambus, Per and Jensen, Erik Steen (2001) Reintroducing grain legume-cereal intercropping for increased protein production in European cropping systems. Paper presented at Fourth European Conference on Grain Legumes: Towards the sustainable production of healthy food, feed and novel products, Cracow, Poland, 8–12 July 2001; Published in *Proceedings of the 4th European Conference on Grain Legumes*, page pp. 52-53. AEP - European association for grain legume research.**

Hauggaard-Nielsen, Henrik; Jørnsgaard, Bjarne and Jensen, Erik Steen (2003) Legume-cereal intercropping as a weed management tool. Paper presented at 4th EWRS workshop: Crop/Weed competitive interactions, Universitá Tuscia, Viterbo, Italy, 10-12 April; *Proceedings and presentations from 4th EWRS workshop: Crop/Weed competitive interactions*. European Weed Research Society.

Hauggaard-Nielsen, Henrik; Jørnsgaard, Bjarne and Jensen, Erik Steen (2003) Legume-cereal intercropping as a weed management tool. Paper presented at 4th EWRS workshop: Crop/Weed competitive interactions, Universitá Tusca, Viterbro, Italy, 10-12 April; *Proceedings and presentations from 4th EWRS workshop: Crop/Weed competitive interactions*. European Weed Research Society.

Hauggaard-Nielsen, Henrik and Jensen, Erik Steen (2004) Intercropping strategies for Europe . [oral] Presentation at *5th European Conference on grain legumes: Legumes for the benefit of agriculture, nutrition and the environment*, Palais de Congrès, Dijon, France, 7 -11 June 2004.**

Hauggaard-Nielsen, Henrik; Jensen, Erik Steen; Aveline, Anne and Crozat, Yves (2004) Grain legumes and nitrate leaching: significance and prevention. [oral] Presentation at *Legumes for the benefit of agriculture, nutrition and the environment*, Palais de Congrès, Dijon, France, 7 -11 June 2004.**

Hauggaard-Nielsen, Henrik; Kinane, Julie; Trydeman Knudsen, Marie and Jensen, Erik Steen (2004) Intercropping and sustainability. [oral] Presentation at *ERA Farming Seminar 2004*, Videolink conference, Risø, Denmark, 26 February 2004.*

Hauggaard-Nielsen, Henrik; Peoples, Mark B.; Andersen, Mette K.; Nielsen, Anders H. and Jensen, Erik S. (2001) Pea-barley intercrop N dynamics in farmers fields. Paper presented at 11th Nitrogen Workshop, Reims, France, 9-12 September 2001; Published in *11th Nitrogen Workshop - Book of Abstracts*. 11th Nitrogen Workshop - Book of Abstracts. INRA - National Institute for Agricultural Research.**

Hauggaard-Nielsen, Dr. Henrik (2002) Grain legumes in organic cropping systems. Paper presented at Grain legumes for sustainable agriculture – LINK, Strasbourg, France, 27-28 September; Published in *Proceedings from Clustered workshops. Workshop 2: towards European expertise on management of cropping systems including legumes*, page pp. 70-74. AEP European association for grain legume research.

Jensen, E.S.; Hauggaard-Nielsen, H.; Aveline, A. and Crozat, Y. (2004) Grain legumes and nitrate leaching: significance and prevention. Paper presented at Legumes for the benefit of agriculture, nutrition and the environment, Palais de Congrès, Dijon, France, 7 -11 June 2004; Published in *Proceedings of the 5th European Conference on grain legumes*, page pp. 63-64. AEP European asociation for grain legume research.**

Jensen, Erik Steen (2003) Organic agriculture - the Nordic, European and global perspectives . Paper presented at NJF's 22nd Congress "Nordic Agriculture in Global Perspective", Turku, Finland, 1-4 July; To be published in *Proceedings from NJF's 22nd Congress "Nordic Agriculture in Global Perspective", Turku, Finland*. Tampere University Print, Tampere, Finland.**

Jensen, Erik Steen (2002) Grain legumes and the European environment. [oral] Presentation at *Press conference: LINK Pulses and health*, Madrid, Spain, 19 April.**

Jensen, Erik Steen (2002) Intercropping – the application of ecological principles in organic plant production. [oral] Presentation at *Course in Organic farming, University of Western Australia*, Perth, Australia, 8 October.**

Jensen, Erik Steen (2002) The application of ecological principle in organic crop production . [oral] Presentation at *3rd Australian Organic Agriculture Symposium*, Perth, Western Australia, 12 October.**

Jensen, Erik Steen (2002) The contributions of grain legumes to an environmental-friendly and sustainable European Agriculture. [oral] Presentation at *LINK dissemination*, Strasbourg, France, September.*

Jensen, Erik Steen and Hauggaard-Nielsen, Henrik (2002) Understanding the role of grain legumes in N cycling of agroecosystems . In *Grain Legumes*, No 36. AEP- European association of grain legume research.*

Jensen, Erik Steen; Hauggaard-Nielsen, Henrik and Jørnsgaard, Bjarne (2002) Grain legumes – their role in European agriculture. [oral] Presentation at *Workshop: Integration of grain legumes in the maize-based production system in semi-arid Sub-Saharan Africa*, KVL, Taastrup, Denmark, 18 November.**

Jensen, Erik Steen; Mørkeberg, Anette; Sørensen, Hilmer and Sørensen, Susanne (2001) Effects from intercropping of pea and barley on the content of protein and bioactive molecules in the seeds. Paper presented at Fourth European Conference on Grain Legumes: Towards the sustainable production of healthy food, feed and novel products, Cracow, Poland, 8-12 July, 2003; Published in *Proceedings of the 4th European Conference on Grain Legumes*, page pp. 90-91. AEP- European association for grain legume research.

Joernsgaard, B.; Christiansen, J.L. and Kuptsov, N. (2002) Adaptation of lupins for Northern European maritime conditions. [oral] Presentation at *The 10' intenational Lupin Conference*, Island, 19-24 June 2002.**

Kinane, Dr. J. and Lyngkjær, Dr. M. (2002) Effect of barley-legume intercrop on disease frequency in an organic farming system . *Plant Protection Science* 38:pp. 227-231.

Salon, Christoph and Hauggaard-Nielsen, Henrik (2001) Managing crop nitrogen and soil dynamics. In *Grain legumes*, Volume 34, No 4, page pp. 18-19. AEP.**

Dansk - Danish

Askegaard, Margrethe (2004) Kaliumtal og kaliumbalancer som redskaber i planteproduktionen [Potassium status and balances as tools in the crop production.]. In *Kaliumtal og kaliumbalancer som redskaber i planteproduktionen*, January, Volume 1, page 63.*

Hauggaard-Nielsen, Henrik (2004) Blandingsforhold ved samdyrkning af hvede og ærter [Proportion of pea and wheat when intercropped]. [oral] Presentation at *Produktion af kvalitetshvede ved samdyrkning med bælgsæd*, Økologiens Hus, Århus, Denmark, 29 January.*

Hauggaard-Nielsen, Henrik (2003) Hvorfor dyrke blandinger?. [oral] Presentation at *Temarække: økologisk Planteavl*, De Danske Landboforeninger, Agrogården, Ringe, Denmark, 14 Februar.

Hauggaard-Nielsen, Henrik (2003) Resultater fra forskning med dyrkning af blandingsafgrøder. [oral] Presentation at *Thematic day to discuss final objectives and field protocols for the project "Produktion af kvalitetshvede ved samdyrkning med bælgsæd"*, Økologisk Landsforening, Århus, Denmark, 13 Marts.

Hauggaard-Nielsen, Henrik (2002) Artsblandinger, udlægsår og eftervirkning. [oral] Presentation at *Talk for organics agricultural advisors arranged by the Danish Agricultural Advisory Centre*, Reserach Station Jyndevad, Danish Institute of Agricultural Sciences, 19 June 2002.

Hauggaard-Nielsen, Henrik (2002) Blandingsafgrøder med korn og bølgsæd – erfaringer og nye udfordringer. [oral] Presentation at *Thematic Field day at the Organic Research Farm Rugballegård - Protein crop production*, Organic Research Farm Rugballegård, Danish Institute of Agricultural Sciences, 6 August 2002.

Hauggaard-Nielsen, Henrik (2002) Blandingsafgrøder og deres bidrag til bæredygtig planteproduktion. [oral] Presentation at *Temadag om dyrkning af bælgplanter og selvforsyning med økologsik protein i 2005*, Økologisk landsforening, Odense, Danmark, 17 December.

Hauggaard-Nielsen, Henrik (2002) Blandsæd – bland afgrøderne og høst fordele. [oral] Presentation at *Salg af økologiske produkter - DLG Økologi*, FAF huset Odense, 16 January, 2002.

Hauggaard-Nielsen, Henrik (2002) Dyrkning af blandinger og høstteknologi. [oral] Presentation at *Samdyrkning og høstteknologi - New Holland DK*, NEW HOLLAND DANMARK A/S, Bibliotekvej 58, DK - 2650 HVIDOVRE, 19 April 2002.

Hauggaard-Nielsen, Henrik (2002) Dyrkning af blandingsafgrøder med bælgsæd. [oral] Presentation at *Temadag om dyrkning af proteinafgrøder*, Økologisk landsforening/Økologisk Rådgivning, Lyngby Landbrugsskole, Roskilde, Danmark, 5 December.

Hauggaard-Nielsen, Henrik (2001) Dyrkning af blandingsafgrøder med bælgsæd. [oral] Presentation at *Økologiske proteinafgrøder - dyrkning og fodring*, Snoghøj IT-folkehøjskole, 28 November 2001.

Hauggaard-Nielsen, Henrik; Jørnsgaard, Bjarne and Jensen, Erik Steen (2002) Arealet med frøbælgplanter bør øges. In *Landsbladet*, January. Landboforeningerne.

Jørnsgård, B. (2002) Sorter af lupin og sygdomme i lupin. [oral] Presentation at *Temadag - Økologisk Landsforening*, Lyngby Landbrugsskole, December 2002.*

Jørnsgård, B. (2001) Erfaringer med dyrkning og kvalitet af lupin. [oral] Presentation at *Efterårskonference*, Hotel Nyborg Strand, Oktober 2001.**

Jørnsgård, B. (2001) Proteinafgrøder - status og potentiale. [oral] Presentation at *Ideforum for Planteavlsudvikling- og forskning*, Landbrugets Rådgivningscenter, Skejby, 19 april 2001.**

Jørnsgård, Bjarne (2004) Dyrkning af lupin. Podning af lupin hvor meget betyder det? Hvordan dyrkes hestebønne? [Growing lupins? Innoculation of lupins, how important is it? How to grow faba beans?]. [oral] Presentation at *Fremad med økologisk jordbrug*, Kalø Landbrugsskole, 20-21 januar 2004.*

Jørnsgård, Bjarne (2004) Valg af lupinsort ved samdyrkning med korn [Ideotypes of lupins in mixture with barley]. [oral] Presentation at *Møde i økologiens hus om samdyrkning*, Økologiens Hus Århus, 29 januar 2004.

Jensen, Erik Steen (2002) Økologisk dyrkning af linser i Danmark?. In *Økologisk Jordbrug*, 8. March. Økologisk Landsforening.*

Jensen, Erik Steen (2002) Økologisk Jordbrug – Er det vejen til en bæredygtig fødevareproduktion? . [oral] Presentation at *Seminar: Mad til verden uden forurening*, Ingeniørforeningen, København K, Denmark, 3 September.**

Jensen, Erik Steen (2002) Research in organic farming and crop diversification. [oral] Presentation at *Kandidat konference*, KVL, September.

Jensen, Erik Steen (2002) Synspunkt - Økologisk jordbrug, fødevarer og miljøet. In *Søndagsavisen*, 9. June. Søndagsavisen a-s.

Jensen, Erik Steen and Hauggaard-Nielsen, Henrik (2001) Valg af frøbælgplantesorter for dyrkning i økologisk jordbrug. [oral] Presentation at *FØJO workshop om forædling af korn og bælgsæd i økologisk jordbrug*, Forskningcenter for Økologisk Jordbrug (FØJO), Dansk JordbrugsForskning, Foulum, Viborg, Danmark, Maj.

Knudsen, Marie Trydeman; Hauggaard-Nielsen, Henrik and Jensen, Erik Steen (2003) Del og hersk. In *Økologisk Jordbrug*, June. Landsforeningen Økologisk Jordbrug.

Knudsen, Marie Trydeman; Hauggaard-Nielsen, Henrik and Jensen, Erik Steen (2002) Blandingsafgrøder giver gevinst. In *Nyhedsmagasinet Økologisk Jordbrug*, 13. December. Landsforeningen Økologisk Jordbrug.

This list was generated on **Fri Dec 10 06:35:23 CET 2004**.

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 advisers. June.

*Askegaard, M. 2002. Managing pulse crops at low K input and effect of catch crops on N and K leaching and crop production on a coarse sandy soil. Feltdage på Jyndevad.

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 Flakkebkerg 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 Økologi, 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 Copengen. 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

F. Scientific education

Askegaard, M. 2003. Management of potassium in low-input systems -with special emphasis on soil test methods and potassium balances. Ph.d. thesis.

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 "Intercropping pea and lupin with barley in Organic Farming" (In Danish: Samdyrkning af ært og lupin med byg i økologisk jordbrug) in relation to WP3

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

Stud. Agro Lars Holdensen finished his master project in September 2003 titled: "Phosphorous stress and cropping of grainlegumes in sole crops and in mixtures with barley – an experiment with fababean, pea and lupin" (In Danish: Fosforstress og dyrkning af bælgplanter i renbestand og samdyrket med byg – et forsøg med hestebønne ært og lupin) in relation to WP2.

Appendix WP3 publication

D9	Paper on the effects of intercropping grain legumes and cereals at different soil types on various parameters	Bellostas et al. (2005) Intercropping of winter vetch and winter wheat for biomass production and enhanced wheat grain baking quality. Eur. J. Agron	To be submitted Jan. 05
		Hauggaard-Nielsen et al. (2005) Grain legume-cereal intercropping – yield and nitrogen use. Eur. J. Agron	In prep.
D10	Paper on multiple resource use by inter- and monocrop of pea and barley	Andersen et al. (2005) Competition dynamics in two and three component intercrops of pea, barley and rape – how is competition best evaluated? Field Crop. Res.	To be submitted Jan. o5
		Hauggaard-Nielsen et al. (2005) Multiple ressource use by pea and barley intercrops. Agr. Ecosyst. Environ.	In prep.
D11	Paper on the competition for multiple resources between intercrops and weeds	Hauggaard-Nielsen et al. (2004) Intercropping with cereals for weed management in grain legumes. Weed Res.	Submitted April 04
D12	Paper on the effect of intercrop design and plant density on the competition with weeds	Hauggaard-Nielsen et al. (2004) Density and relative frequency effects on competitive interactions and resource use in pea-barley intercrops. Field Crop. Res.	Submitted July 04
		Jørnsgaard et al. (2005) Use of competitive models to investigate pea-barley interspecific competition. J. Appl. Ecol.	In prep.
D13	Guidelines for intercropping grain legumes and cereals for multiple functions in organic cropping systems	Contributed to the development of internet based guidelines: http://www.okologiens-hus.dk/proteiner/ http://eksperimenter.dk/samdyrkning/xtema-samdyrk-beskr.html	

G. National and international cooperation

National partners:

Collaboration with projects and scientist in DARCOF played a key role for the people involved in the GENESIS project. Initially the people involved in the VEGCATCH project (http://www.darcof.dk/research/darcofii/i10.html) and the on-going "Crop rotations for cereal production in organic farming" (http://web.agrsci.dk/pvj/plant/croprot/descripuk.shtml) was used when developing experimentation. While evaluating field data after the first and also the second growth season substantial interchange of experiences was taking place with the GRAINLEG group (http://www.darcof.dk/research/darcofii/vi4.html). A joint project meeting focusing on grain legume diseases was established in June 2002 together with a more general workshop dealing with grain legume cropping held at Flakkebjerg (DIAS) in December 2004. At the final stages of GENESIS it was it obvious that collaboration with the NIMAB project (http://www.darcof.dk/research/darcofii/i4.html) would be fruitful in order to address the grain quality effects observed on the cereals when intercropped with grainlegumes. However, collaboration with NIMAB was limited due to the project time schedule. Another collaborator when focusing on intercropping and effects on cereal quality was Johannes Ravn Jørgensen (DIAS, Flakkebjerg) supporting initial ideas and access to NIR/NIT equipment for additional wheat grain quality assessments.

Persons from the seed industry, plant breeders and local as well as national agricultural consultants were invited to several GENESIS project meetings. Especially in the autumn after the first and second growth season close bonds between the different groups was built and a great deal of knowledge transfer was established among the different key-persons. Together with this the GENESIS scientists were often at farmers meetings and participated in field days arranged by the Danish Agricultural Advisory Service, The Danish Association of Organic Agriculture and sometimes also local Agricultural Advisory centers. While directing research findings and ideas to the farmer community the GENESIS group realized that several initiatives was taking place testing different grain legumes, cropping strategies etc. without any scientist guidance. Participating in farmer days it was obvious that grain legume cropping and especially intercropping gained a lot of attention and serious considerations. The GENESIS group was also involved in discussion and participation of two projects "Proteinafgrøder" (http://www.eksperimenter.dk/eksperimenter/faktasider/xproteinafgr.html) and "Produktion af kvalitetshvede ved samdyrkning med bælgsæd" (http://eksperimenter.dk/samdyrkning/xtema-samdyrk-beskr.html) coordinated by The Danish Association of Organic Agriculture.

An interpretation of interactive effects between intercrop component activities and soil processes is extremely complex. Thus, to really interpret all these processes at once and under variable and interacting conditions, dynamic simulation models of these systems are nearly essential. A very fruitful collaboration with Jørgen Berntsen (Foulum, DIAS) using the FASSET model was established.

International

The Nordic working group focusing on potassium in organic farming, where MA participates, reveals many of the issues in WP2.

During the early start of the GENESIS project ML and JK discussed ideas and research questions according to the work on intercropping and disease with two other groups working in this field from University College Dublin, Ireland (Finnian Bannon) and Swedish University of Agricultural Sciences, Uppsala, Sweden (Jonathan Yuen). Unfortunately, no formal continuation of this sharing of ideas continued during the rest of the project.

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.

HHN met several competent weed scientists interested in organic farming and interspecific competitive crop-crop and crop-weed interactions during a workshop held in Viterbo (2003) arranged by European Weed Research Society. Several colleagues met on this workshop participate in the COST Action 860 (http://www.cost860.dk/) with several DARCOF scientists as key-players.

ESJ has strong links with European scientists within all disciplines of grain legume research through his involvement in the scientific committee of The European Association of Grain Legume Research (AEP). Partly through this network of grain legume researchers the GENESIS project among other activities has led to two EU funded projects very much in line with the achievements in WP3 and the GENESIS project as such. The EU funded 5^{FP} INTERCROP (www.intercrop.dk) project will develop the French simulation model STICS to simulate dual intercropping using field data from 5 different European partners. Among other activities in this project it is expected that final work with STICS will improve our knowledge regarding the mechanisms involved when intercropping grain legumes and cereals. Together with the involvement of the GENESIS research group in several farmer oriented dissemination events the INTERCROP project will likewise contribute with such activities to address more practical issues of intercropping. With involvement in the EU funded 6^{FP} GRAIN LEGUMES IP (www.eugrainlegumes.org) special emphasis on leaching of N in autumn/winter after grain legumes versus intercropped grain legumes will be conducted. It was not possible to come up with any conclusions on this very important aspect of grain legume cropping in the GENESIS field activities but it is expected that this EU project will contribute to develop methods to prevent nitrate leaching, including designs of cropping systems with more closed nutrient cycles. In the same EU projects the very significant findings according to effects of intercropping on plant diseases will be followed up with more detailed studies.

H. Critical reflection on the project

Project relevance

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 be a surplus in 2002. 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 increased proportion of grain legumes in the organic rotations raise the question of rotational diseases in the grain legumes. It is necessary to maintain the plant health by careful consideration of the number of years between grain legumes crops and obtain knowledge on the potential to use of different species in the rotation. More research is required to increase the yield stability of grain legumes in organic farming systems.

Consortium establishment and function

The establishment of the GENESIS multidisciplinary consortium was based on the merging of proposals by the FØJO board. The procedure may not necessarily stimulate interdisciplinary research, since the partners have each of them already defined their main tasks. There may be a risk that the project may just be a set of smaller project that runs more or less independently. It is very much the responsibility of the coordinator and the participants. It is our impression that interdisciplinary activities between WPs occurred, but probably was too limited, or possibly not prioritized high enough among participants, which may have put restrictions on the recognitions of new interdisciplinary knowledge. While joint field trials and regular meetings encouraged interaction between the participants, we could build on it even more especially in the area of data analysis and interpretations. An internal data workshop pointing a significant findings and obstacles is suggested. We also suggest that that care is taken in the future, that there is a certain volume of the WPs, since too may small elements also enhance the risk of not sufficient coherence in the project.

Scientific methodology

The GENESIS research was based on field experiments, which causes large variation in results and set natural limitations on the possibilities to repeat non-optimal experimentation. The shared field experiments between different WP groups were working excellent. It reduced costs and resources used compared to separate individual WP experiment set-ups. On the same time field trials were more comprehensive, than if they were set up individually. Another surplus of such joint activities is that several aspects of the intercrop system could be viewed at the same time e.g. weeds, disease and nitrogen accumulation sharing collected data. From a practical point of view joint expertise also reveal that problems are envisaged and solved quicker than if working alone.

What can be improved?

The choice of field experiments as method is justified by the objectives of the research, aiming at new production methods for improved protein supply in organic farming. This aim is not easy and the use of ^{15}N natural abundance technique for N_2-fixation determinations is a good example for such challenges. This technique was used because a very sensitive mass spectrometer facility at Risø was available, and because it was cheaper than the ^{15}N enrichment techniques because no pre-treatment of ^{15}N enriched material or solution is necessary. Furthermore, where natural abundance and enrichment techniques have been compared, field estimates of N_2 fixation is often similar, with similar precision. However, on the sandy soil at Jyndevad the level of natural ^{15}N abundance in the soil was low. Using the natural abundance method to estimate N_2 fixation a minimum of at least two in the $\delta^{15}N$ value of the reference crop with preferable concentrations up to six for optimum precision was not achieved. These methodological difficulties were also influencing determination of the effect of K-status on the N_2-fixation in WP2. The low natural ^{15}N abundance may be caused by a yearly deposition of N-difference around 18 kg/ha in 1987/88 diluting the soil ^{15}N abundance by the lighter ^{14}N isotope. Atmospheric deposition might even be increased by today due to a major increase in pig production in this area. Other factors might also have influenced the natural ^{15}N abundance like cultivation, fertilization, particle size, depth etc. For future experimentation in Jyndevad involving ^{15}N a better knowledge on the soil and N-dynamics at the site should be established before initiation of experiments.

The high costs of field experiments made it necessary to simplify the WP2 potassium experimental design to two treatments; without and with K application. It would be relevant to make further investigations to detect soil K status thresholds for the different crops and thereby give more detailed recommendations to the farmers.

Although it is very relevant to study the effect of organic farming and intercropping of cereals and legume plants on the nutritive quality of the grains and seeds it is also obvious that a number of various factors including soil type, sowing time, local climatic conditions throughout the growing period, competitions from weed a.o. may influence the quality significantly. This was also the case in the present study. Furthermore, the selection of varieties, ratio between plants from cereals and legumes in intercropping for the specific growing season may have a significant effect.

A major obstacle working with grain legumes in the field causing considerable field variability and sometimes destroying whole experiments are bird damages. Especially at KVL in Taastrup (the sandy loam site in the present project) this was causing major problems. A field phosphor deficiency experiment was destroyed in year 2001 and 2002 by birds. In accordance with the DARCOF administration the field experiment was replaced by greenhouse pot experiments. The conclusions regarding the grain legume species sensitivity to low soil P, based on the greenhouse experiments can only with precaution be extrapolated to field conditions. Due to these severe damages coverage of experiments by nets was organized for some of the other 2002 field activities. However, the cost of technical assistance to establish such netting was comprehensive and the project budget was not able to cover such expenses. For the considerable 2003 field activities on this site no netting was established and luckily no major bird damages was found. It is not recommended to take such changes, but on the other hand it is difficult to explain the funding bodies such extra field expenses while working with grain legumes.

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 and conclusion. As an example the precrop and fertility management may influence estimates of biological N_2-fixation due to the amount of available soil mineral N. As a consequence of this it is important to have experimental field facilities making it possible to place the experiment in well-established organic sites on the same place in the rotation during the e.g. 3 subsequent years.

Finally, the analysis of the two major dry matter fractions in cereals, peas and fababeans - protein and starch - are central in the estimation of the nutritional quality. From these analyses the nutritional quality may generally be estimated with sufficient accuracy. Thus, the protein quality can be calculated with reasonable accuracy for practical feed evaluation from specific equations based on the protein level in the different feedstuffs. The preliminary analyses of anti-nutritional factors did not indicate any particular effect of these compounds in the used varieties. Most probably, these compounds are mainly related to the specific variety, rather than environmental influences. Future studies should have a budget size that enable us to perform a complete chemical and nutritional characterization of the quality of sole crops and intercropped grains used for the feeding of animals. Unfortunately, the present analysis was not regarded as sufficient for setting up appropriate guidelines for feeding using protein sources of local origin. More knowledge is required on quality of organically produced grain legumes and their value for animal feeding, especially regarding the requirement for self-sufficiency in 2005.

8. Budget

A. Account for any change in budgets

B. Budget for the whole project (1.000 DKK)

Year:	**Consumption before 2004**	**Consumption 2004**	**Original budget**
Man-months			147,6
Scientific personnel			
Technical personnel			

Year:	**Consumption before 2004**	**Consumption 2004**	**Original budget**
Salaries	4096	299	4374
Scientific personnel			3309
Technical personnel			1065
Other operational costs	1225	73	1071
Equipment			
Others (please specify)	8		30
Direct costs	5331	371	5475
Indirect costs (20% of direct costs)	1067	74	1095
Total	6399	445	6570

Comments: The difference between total consumption (6844 kkr) and the total original budget is due to Risø co-financing.

9. Signatures and stamps

Name	Institute	Date	Signature
Head of project Erik Steen Jensen	Risø National Laboratory	30.06.2004	

Appendix I. Detailed budget

A. Budget for each participating institute (1.000 DKr)

Name of Institute:

Year:	**Consumption before 2004**	**Consumption 2004**	**Original budget**
Man-months Scientific personnel Technical personnel			

Year:	**Consumption before 2004**	**Consumption 2004**	**Original budget**
Salaries Scientific personnel Technical personnel			
Other operational costs			
Equipment			
Others (please specify)			
Direct costs			
Indirect costs (20% of direct costs)			
Total			

Comments:

B. Budget for each participating department (1.000 DKK)

Name of Institute and department: WP1 Department of Agricultural Sciences, KVL (Bjarne Jørnsgård)

Year:	**Consumption before 2004**	**Consumption 2004**	**Original budget**
Man-months			
Scientific personnel	21	1.5	23
Technical personnel	8	0	9

Year:	**Consumption before 2004**	**Consumption 2004**	**Original budget**
Salaries	913	58	1064
Scientific personnel			792
Technical personnel			272
Other operational costs	167	30	103
Equipment			
Others (please specify)			
Direct costs	1.081	88	1167
Indirect costs (20% of direct costs)	216	17	233
Total	1.297	105	1400

Comments:
The decrease in salaries and the corresponding increase in other operational costs is caused by a change in the Invoice practice 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. There has also been a minor shift from technical to scientific total costs. This practice has been changed after the onset of the GENESIS programme.

Name of Institute and department: WP2, DIAS, Department of Agroecology M. Askegaard)

Year:	**Consumption before 2004**	**Consumption 2004**	**Original budget**
Man-months Scientific personnel Technical personnel			

Year:	**Consumption before 2004**	**Consumption 2004**	**Original budget**
Salaries	440	85	416
Scientific personnel			352
Technical personnel			64
Other operational costs	223	35	368
Equipment			
Others (please specify)			
Direct costs	663	120	784
Indirect costs (20% of direct costs)	134	24	156
Total	797	144	940

Comments:

Name of Institute and department: WP3, Previously KVL- now Risø (Erik Steen Jensen)

Year:	**Consumption before 2004**	**Consumption 2004**	**Original budget**
Man-months			35
Scientific personnel			16
Technical personnel			

Year:	**Consumption before 2004**	**Consumption 2004**	**Original budget**
Salaries	1174	156	1444
Scientific personnel			
Technical personnel			
Other operational costs	514	8	326
Equipment			
Others (please specify)	8		30
Direct costs	1696	163	1800
Indirect costs (20% of direct costs)	339	33	360
Total	2035	196	2160

Comments: The project was moved from KVL to Risø 1. August 2003.

Name of Institute and department: Risø WP4 and WP5 (Michael Lyngkjær og Per Ambus).

Year:	**Consumption before 2004**	**Consumption 2004**	**Original budget**
Man-months			
Scientific personnel	31	0	30
Technical personnel	10.8	0	7.2

Year:	**Consumption before 2004**	**Consumption 2004**	**Original budget**
Salaries			
Scientific personnel	1009		971
Technical personnel	281		185
Other operational costs	204		171
Equipment			
Others (please specify)			
Direct costs	1494		1326
Indirect costs (20% of direct costs)	298		265
Total	1793		1592

Comments:

Name of Institute and department: Danish Institute of agricultural sciences, Department of Animal Nutrition and Physiology

Year:	**Consumption before 2004**	**Consumption 2004**	**Original budget**
Man-months			
Scientific personnel	2		3,7
Technical personnel	9,4		8

Year:	**Consumption before 2004**	**Consumption 2004**	**Original budget**
Salaries			
Scientific personnel	76.130		116
Technical personnel	203.379		184
Other operational costs	117.152		98
Equipment			
Others (please specify)			
Direct costs	396.661		398
Indirect costs (20% of direct costs)	80.336		79,6
Total	476.997		478

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

Name of Institute:

Year:	Consumption before 2004	Consumption 2004	Original budget
Man-months Scientific personnel Technical personnel			

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

Comments: