I.5 Grain legumes and cereals - new production methods for increased protein supply in organic farming systems

Acronym: Genesis

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1. Summary

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

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

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

2. Research group

A multidisciplinary research team (agroecologist, weed scientist, crop scientists, agronomists, animal nutritional physiologists, entomologist, plant pathologist, microbial ecologist, plant nutritional physiologist) from KVL, DIAS and Risø has been formed to carried out the tasks. The research work will mainly be carried out at two experimental sites: the experimental station at Højbakkegård (KVL) and St. Jyndevad (DIAS) during 2000-2003.

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3. Introduction

Animal production depends on a sufficient supply of protein crop and cereal grains. Organic cropping systems for dairy production with high self-sufficiency have successfully been developed in Denmark in recent years. A parallel development for production of pigs and poultry has not taken place. The lack of reliable protein crops to satisfy the diet of monogastric animals in combination with lower cereal yields in organic farms, causes higher product prices and have been the limiting factors for increased production of pigs and poultry in organic farming (Norholt, 1997). A certain import of conventionally produced protein feed sources is presently allowed on organic farms, e.g. soybean meal, free of genetically modified soybean grain, and oilseed rape cakes. However, from 2005 all feed used in animal production must be organically produced.

Grain legumes (pulses) such as field pea (*Pisum sativum* L.), faba bean (*Vicia faba* L.), lupines (*Lupinus* ssp.) and vetch (*Vicia sativa* L.) are rich in protein compared to other starchy plant products, e.g. cereals. The grain legume proteins are rich in lysine, and suited for animal feed formulation, especially for pigs and poultry, as complements to cereals. In France most feed formulations for pigs contain 25-30% peas (Bourdillon, 1999). Danish feeding experiments have showed that 30% peas can be incorporated in the feed for pigs, and similarly for poultry (Jakobsen, 1986). Furthermore, grain legumes are valuable in human diets low in meat.

In addition to being a valuable protein and energy source in animal feeding, grain legumes benefit the organic cropping system, via biological fixation of atmospheric N_2 - a fundamental process for maintaining soil fertility in organic farming systems. Other positive effects in the crop rotations are recycled N-rich crop residues and the break-crop effect, e.g. in relation to take-all (*Gaeumannomyces graminis*) in cereals-rich rotations (Lampkin, 1990; Jensen, 1997).

In 1999 about 5.0 Mt of grain legumes were produced in the European Union, 80% was peas and 85% was used in animal feeding within the EU, but no data seems to be available on the amount of organically produced dry grain legume seeds in EU. In the EU there is room for increasing the grain legumes production in conventional systems with a factor four (Pahl, 1999), and the production can potentially be increased in organic farming. The gap between the demand and production of feed protein within the European countries has for many years stimulated research on alternative protein sources and the Common Agricultural Policy is to encourage the production and use of home-grown and protein-rich crops in animal feed.

In Denmark there is limited organic production of grain legumes for harvest at the dry seed stage, either as mono- or intercrops with cereals (Aveline, 1999). However, pea and vetch are often intercropped with cereals for silage production in organic systems (Aveline, 1999). The small production of grain legumes for harvest as dry seeds is probably due to:

- The demand for locally produced organic protein feed sources has not yet been pronounced, due to the import of alternative sources, when needed in feeding of monogastric animals.
- Systems with milk production have a high proportion of legumes (and N_2 fixation) in the rotation, due to grass-clover pastures, and consequently less room for grain legumes in the rotation.
- Grain legumes have a reputation of low yield stability.

The yield variability in grain legumes is related to their intolerance to water stress and harvest difficulties either because of lodging or late maturity. Grain legumes may also suffer from pathogen attack causing diseases, e.g. *Ascochyta* spp., *Botrytis* spp., *Erypsiphe* spp. (Jimenez Diaz et al., 1999). This may strongly restrict the yield and influences grain quality, due to altered carbohydrate metabolism, protein remobilization and free amino acid translocation within the grains. Grain legume seeds vary in quality, mainly due to environmental conditions (Bastianelli et al., 1995), and grain legumes are weak competitors for weeds and therefore less favoured in organic crop rotations with weed problems (Lampkin, 1990).

The aims of this project is to:

- determine the potential for grain legume production in organic cropping systems on different soil types,
- identify eventual obstacles to the grain legume production,
- evaluate methods, e.g. intercropping with cereals, to overcome some of the obstacles, for increased production of high quality grain legumes seeds, and
- give recommendations for species and cultivar choice depending on production system, soil type and use of grain legumes seeds in the organic animal production.

We will study pea, faba bean and narrow-leafed lupine (*Lupinus angustifolius*) types for organic cropping systems. The main focus will be on grain production, nitrogen fixation, intercropping with cereals, effect of K and P availability on yield and nutrient uptake, interactions between plant nutrition and plant fungal disease resistance, competition between grain legume crop and weeds and on quality parameters of grain legume seeds and intercropped cereal grains.

4. State of the art

There is a significant knowledge on the growing of grain legumes and cereals in European conventional cropping systems, but a lack on knowledge and suggestions for overcome limitations to the growing of grain legumes in organic cropping systems.

Grain legume species and types for mono- and intercropping with cereals in organic cropping systems

To meet the requirement of monogastric animals 25 to 35 % of the feed should consist of a high protein product. I an organic farming system the majority of this should be produced on-farm. This requires the on-farm crop production from an organic production system should consist of grain legumes, depending on the protein content. This requires a high proportion of grain legumes in the organic cropping system. The crops with the greatest potential for this purpose are peas, faba beans and lupines, all having potential high biomass production under Danish conditions (Flengmark, 1984). However, each of them has advantages and disadvantages in the organic production system with respect to crop rotation, weed and disease control, nutrients requirements and quality for feeding monogastric animals:

- Pea is the best-adapted crop to Danish growing conditions, it has a stable and early ripening, but as monocrop (pure stand) the crop is susceptible to water stress, especially during the vegetative and early reproductive growth stages, problems are observed in mechanical weed control and at harvest.
- Faba bean has a high production potential and a higher protein content than peas and few problems with lodging however ripening is often late, yield variable and diseases and aphids can cause problems (Lampkin, 1990).
- Lupine has the greatest protein content of the three species, and the ability to mobilise phosphorous. However, it suffers from yield instability and late ripening, due to excessive vegetative growth (Flengmark 1984, Braum and Helmke, 1995).

For peas being the plant and having a climbing growth form the project will focus on intercropping with cereals. For faba beans and lupines being less adapted and having late and unstable ripening focus will also be on the genotypic variation in phenological development, ripening, biomass and seed production and nitrogen fixation in order to optimise the choice of variety/type for inter- and monocropping.

In an organic rotation system with monogastric animals a grain legume crops should preferentially appear frequently in the rotation in order to cover the whole or part of the protein supply for feed on the farm. In such system weed control can cause problems (Rasmussen, 1999). An integrated strategy, based on mechanical weed control, rotation and the competitive ability of the crop towards the weeds, is needed. Intercropping of grain legumes with cereals might improve the weed suppression, but the importance of growth form of the grain legume in this context is not investigated. A set of ideotypes varying in time for the stem elongation, final plant height and branching type has been identified in *Lupinus angustifolius*. Some of these genotypes possess improved agronomic characters in earliness, stability and yield (Christiansen et al., 1998). They will serve as a set of model plants in the study of the importance of the growth form of the legume for intercropping with cereal and for the competitive ability against weeds. New types with determined growth forms might improve earliness and stability.

Intercropping of grain legumes and cereals - resource use and weed management

Intercropping is defined as the growth of two or more plant species simultaneously in the same field during a growing season. Due to agricultural intensification in terms of plant breeding, mechanisation, fertiliser and pesticide use during the recent 50 years intercropping has disappeared from the Danish cropping systems. The plant production in organic farming systems resembles in many ways conventional systems, e.g. the growing of monocrops, because farmers adopt the methods, which are familiar to them, when converting to organic farming. Intercropping is the practical application of ecological principles, such as diversity, competition and other natural regulation mechanisms. More specifically intercropping offers the potential of:

- improving the use of limited resources (nutrient, water, light and land) (Willey, 1979; Anil et al., 1998; Jensen, 1996),
- increasing the input of N_2 fixation in the cropping systems,
- increasing the yield compared to monocropping and an improved yield stability, due to self-regulation in the crop (Willey, 1979). This will give the organic farmer a better insurance against total crop failure and will safeguard the farmers earnings,
- improving the product quality, e.g. greater protein content of cereals, via planned competition, and
- providing an ecological method via competition, natural regulation mechanisms and planned biodiversity to manage weeds, diseases and pests, which can reduce the cost of energy for mechanical or of manual weeding and improve the quality of product.

However, there has been only limited research in intercropping systems in temperate agro-ecosystem, mainly because these systems are considered to be most relevant to low-input farming and due to the complexity of intercropping. Results from pea-barley and wheat-fababean intercropping in conventional systems have shown up to 20% yield advantage from intercropping compared to growing the crops as monocrops (Jensen, 1986; 1996), but limited results are available from organic systems and with other grain legumes than pea. We will study the effect of and potential for intercropping pea, faba bean and narrow-leaf lupine with cereals on two different soil types in organic systems. Our hypothesis is that intercropping will results in an yield advantage and a greater yield stability compared to monocropping.

Intercropping can improve the capture and utilisation of growth factors, such as light, water and nutrients (Willey, 1979). Advantages of intercropping compared to monocropping are due to the interactions between intercrop components, caused by differences in the competitive ability for growth factors (Trenbath, 1976). If intercrop components differ in their use of growth factors in such a way, that when they are grown in intercrop, they can "complement" each other in time and space, they may use growth factors more efficiently, than when grown in monocrops (Willey, 1979). In terms of competition this means that the components are not competing for exactly the same ecological niches and that interspecies competition is weaker than intraspecific competition for a given factor (Vandermeer, 1979). There is evidence from tropical research that intercropping can increase both the capture of water and of light (Fukai and Trenbath, 1993). Research on intercropping in temperate crops has mainly focussed on the use of a single growth factors by the crop in the experiments. The main reason for this is the lack of methodology to study the capture and use of water and light by the individual components of an intercrop. Our aim is to simultaneously study the use of multiple resources in the intercrop-weed community. We will study the capture of soil-derived nitrogen, biologically fixed N, P and K, water and light in pea barley intercrops. New methodology involving the use of stable isotopes, sensors and other approaches will be employed to improve the knowledge on multiple resource use by the intercrop, and the effect of multiple resource use in relation weed regulation in the crop.

Nitrogen is often the most limiting factor in organic plant production and surplus levels of nitrate in the soil after some crops, e.g. grain legumes grown as monocrops can increase the risk of leaching losses in the autumn and winter in north-western Europe (Jensen, 1997). Our hypothesis is that intercropping grain legumes with cereals can reduce this risk, due to a better use of soil N and a more balanced chemical composition of crop residues.

Most intercrops are grown as mixed intercrops, which means that the different species are sown at the same time in the same row. This intercropping design often causes a strong interspecific competition causing a low yield and N_2 fixation by the component grain legume. A survey made on organic farms indicated that organic farmers, who use intercropping use a variety of methods for establishing the crops (Aveline, 1999). We will study the effect of intercropping design on yield and weed suppression compared to monocrops. Our hypothesis is that intercropping will reduce weed biomass compared to the growing of the grain legume as a monocrop.

French organic farmers intercrop pea if there are weed problems on the soil (Dr. Yves Crozat, Angers, personal communication). However, there is not enough knowledge regarding the effect of intercropping on weed growth. There are several mechanisms by which intercrops can influence weeds. One hypothesis ('weed suppression') is a greater yield and less weed growth will be the result if the intercrop is a more efficient competitor than the monocrops for acquisition of plant growth factors (light, water and nutrients) relative to the weed (Liebman and Dyck, 1993). 'Weed-tolerance' is when the intercrop are advantageous compared to monocrop without suppressing the weeds below the level observed in monocrops, because the intercrop is more efficient in utilising the growth factors, that are not utilised by the weed, than are the monocrops (Liebman and Dyck, 1993). In this project we will test these hypotheses.

Most intercropping has been developed with components of the crop grown for the same purpose, mainly harvest as grain or silage. However, intercrops can be designed to have multiple functions, e.g. weed regulation by one component and grain production by another. Intercropping also offers the potential to use the ecological principle competition to manipulate product quality. As an example it can be difficult to increase the protein content of wheat grown in pure stand, since increased N-supply generally will increase also the dry matter yield and “dilute” the increased N uptake. In an intercrop of wheat-faba bean, it is likely that wheat is much more competitive for N than faba bean, but faba bean may compete for such factors as light, water causing the relative increase in wheat protein content to be enhanced relatively more than the dry matter production. As a consequence protein content is increased (Jensen, 1986). This hypothesis will be tested in the project.

Performance of grain legumes and cereals at low potassium and phosphorus level

Limitations on nutrient import to organic farms may result in a general nutrient deficiency, and potassium (K) and phosphorus (P) deficiency is expected to become significant (Josefsen, 1999). In organic crop production the limited amount of manure will normally be applied to the crops, which does not fix nitrogen in order to optimise the N use. Consequently, the legumes will have to rely on plant available soil potassium (K) and phosphorus (P).

The protein production may be limited in K deficient soils through reduced translocation of nitrate and amino acids and reduced protein synthesis (Blevins, 1985). Deficiency may also influence the legume-*Rhizobium*-symbiosis, and dry matter and total N accumulation in leguminous crops are responsive to K fertilisation (Stanley and Collins, 1985). Influence of P availability on N_2-fixation and protein content is expected in grain legumes, as nitrogen fixation is a highly energy demanding process and P is essential in energy requiring processes in the plants. In a P deficiency situation peas responded markedly in growth and nitrogenase activity to increased P (Berg and Lynd, 1985; Jakobsen, 1987).

The grain legumes possess different tolerance to low K and P status in the soil. Lupines seem to be less responsive, maybe due to a more efficient nutrient uptake (Wasserman, 1986) whereas peas show high response to K and P application (Berg and Lynd, 1985).

The main source for K uptake in plants is the exchangeable K fraction in the soil. However, due to high K leaching losses from sandy soils (Simmelsgaard, 1996) this fraction may be very low. In an organic crop rotation experiment on a coarse sandy soil (Olsen *et al,* 2000), we have measured an exchangeable K level, much below the level that would activate K-fertilisation on conventional farms (unpublished data). The grain legumes seemed to have been able to cover their K requirements from the soil K sources in the first three experimental years, whereas we observed severe K-deficiency symptoms in the cereal crops. Coarse sandy soils cover nearly 25% of the agricultural area in Denmark.

Previously, added fertiliser P can be immobilised and may therefore be unavailable for following crops. Grain legumes are known to excrete organic acids from the roots, which in many soil types mobilise and increase uptake of P (e.g. Gardner et al., 1983; Li and Barber, 1992). It can be speculated that the P mobilising ability of the grain legumes can increase the P availability for a cereal intercropped with the legume and for a following crop. Cultivation of pigeonpeas was found to increase the total P availability in cropping systems with low available P (Ae et al., 1990), but this effect has not been confirmed with peas, faba beans or lupines. For an organic rotation system based on grain legumes and cereals, this effect could be important for the productivity of the system at low soil P levels. More knowledge is required about the influence of low K and P status on the production and quality of protein in grain legumes and cereals in order to optimise the protein production.

Plant health in grain legume and cereal crops

Plant health is a key factor for yield stability, quantity and quality. Maintaining plant health might become an increasing problem in Danish organic farming as the demand for more specialised crops like e.g. cereals for malt and bread and legumes for protein increases. This is because these crops are traditional grown as monocrops (pure stands) in conventional farming, where plant health is obtained by commercial fertiliser and pesticides Therefore, the breeding has been directed towards other traits than those of importance in organic farming.

Disease resistance is an important key factor contributing to plant health in crops. Resistance of plants depends on their genetic background but is also highly affected by the physiological status of the plants due to environmental conditions like i.e. nutrient supply and cropping/farming system. As mentioned earlier K deficiency in sandy soils expected to increase in organic farming systems. This influences the physiology and quality of the crop and is thereby also expected to modify the level of disease resistance in the crop. Similarly may cropping systems, especially intercropping systems involving different plant species like grain legumes and cereals, also change the physiology and quality of individual plants in the crop and thereby modify the overall level of disease resistance in the crop.

Much experimental evidence is available indicating that plants are less affected by pests and diseases, if they are optimally supplied with nutrients. The susceptibility of field crops to many biotic problems increases with increasing amounts of available nitrogen (N). High N uptake is often accompanied by a relatively lower concentration of nutrients in the plant other than N, such as K and silicon (Si), which play an important role in the plant's defence system. Strengthening host plant resistance by means of proper nutrient management therefore appears to be an ideal disease management concept. In cereals attacked by the powdery mildew fungus, increased N increases the susceptibility of the host plants (Jensen and Munk, 1997), possible due to decreased production of phenolic acid involved in the papilla resistance response (Sander and Heitefuss, 1998). Deficiency of K often leads to increased disease susceptibility (e.g. Trolldenier, 1983), this may be due to reduced tissue strength or interference with Si uptake and supply to epidermal cells of leaves. The role of Si in plant disease resistance is both as a passive mechanical protection and through activation/enhancement of anti-fungal activity like phytoalexin (Fawe et al., 1998, Cherif et al., 1994).

Components of intercrops are often less damaged by diseases caused by pathogens, than when grown as monocrops, but the effectiveness of this reduction often varies unpredictably. There are three different ways intercropping may reduce diseases, all involving reduced growth rate of the attacking pathogen population (Trenbath, 1993):

- The different crops may interact, changing the susceptibility of the attacked host, e.g. by changed availability of nutrients. Bulson et al. (1997) illustrated this in a study of wheat and field beans as intercrop in an organic farming system. Here they found that the N content of the wheat grain and whole plant biomass was significantly increased when the density of beans in the intercrop was increased. In general the levels of disease on the wheat were low, but mildew (*Blumeria graminis*) increased significantly as bean density (and thereby also N) increased.
- The crops may interfere directly with dispersal of the pathogen. This was the case for splash dispersal of *Septoria tritici* blotch (*Mycosphaerella graminicola*) pycnidiospores in wheat-clover intercrops (Bannon &

Cooke, 1998) and of *Colletotrichum acutatum* conidia in a sudangrass cover crop (Ntahimpera et al., 1998).

- The environment within the intercrop (the microclimate) may change to unfavourable conditions for the pathogen. Boudreau & Mundt (1992, 1994) investigated how maize influences bean rust (caused by *Uromyces appendiculatus*) in maize-bean intercrops and suggested that microclimate in addition to dispersal may have a strong impact on disease.

Quality of grain legumes and cereals in relation to feeding of monogastric animals and food production

Compared to conventional farming in Europe, organic farming is even more dependent on home-grown protein sources because the animal production needs to be based mainly on home-grown crops. Furthermore, during the last years it has become a common practise in conventional farming to improve the quality of dietary protein considerably by supplementation of the first limiting amino acids, i.e. lysine, methionine, threonine and eventually also tryptophan (Boisen, 1998). These supplementation's significantly reduce the protein requirement as well as the pollution problems from the surplus nitrogen in animal feeding (Boisen, 1993). However, according to the principles for organic farming the use of industrial products are not acceptable. Therefore, it is essential to identify species and varieties of agricultural crops, which can produce a good yield under organic farming conditions and, furthermore, can be used as suitable ingredients in animal feeds.

Due to the climatic conditions in Denmark, the most promising pulses as home-grown crops are expected to be peas, faba beans and lupins. However, the concentration of protein in peas and faba beans is only about half of that in soybean meals while the concentration of protein in lupines is intermediate to the other (Wiseman and Cole, 1988). Common for the three legume species is a deficiency in sulphur amino acids in relation to the ideal amino acid composition for monogastric animals (Wiseman and Cole, 1988). Furthermore, lupines are low in tryptophane.

Although cereal proteins are generally much higher in sulphur amino acids this can normally not compensate for the deficit in pulses (Boisen, 1997). Furthermore, cereal proteins are generally very low in lysine, which will be the first limiting amino acid in most relevant pig diets. It is therefore important for the organic farming system to develop new strategies for minimising the imbalance of amino acids for animal feeding. Thus, the use of high-lysine barley varieties is one option for a considerable improvement of the protein quality of the diets (Boisen, 1998). Although the yield of these varieties are generally slightly reduced, and consequently have not yet been used generally in conventional farming, they may be very suitable in organic plant production where the growing conditions will be different.

Other general properties of grain legumes can be related to a relatively low availability of the carbohydrates. Thus, the level of dietary fibre is relatively high in lupines (Bach Knudsen, 1997), while the digestibility of starch is relatively low in peas and faba beans (Canibe and Bach Knudsen, 1997). Both of which may restrict the inclusion levels of pulses in diets for monogastric animals.

Recently, quick and reliable analysis methods have been developed for determining the digestibility of the different nutrient fractions in the actual samples of single feedstuffs and diets (Boisen & Fernandez, 1995 and 1997). On the other hand, a more specific biological attribute of grain legumes, which may be considered positive in animal feeding, is the relatively high level of non-digestible oligosaccharides (NDO). NDO in the form of raffinose oligosaccharides are found in levels of 5-8% in the three types of pulses (Bach Knudsen and Li, 1991; Bach Knudsen, 1997) and were earlier considered as constraints because of the rapid gas-production during intestinal fermentation causing flatulence (Fleming & Reichert, 1983). Recent studies, however, indicate that NDO may have a positi*ve* influence on the gastrointestinal environment by stimulating specific strains of bacteria *(Bifidobacteria*) and thereby reduce, or even eliminate, the risk of colonising by pathogenic micro-organisms (Nemcova et al, 1999)

Another general property of pulses is a frequent high level of a number of different antinutritional factors (ANFs), including protease inhibitors, tannins, lectins and alcaloids. The biological effect of these compounds may often be most pronounced in a reduced protein digestibility and utilisation, which can be measured in model animals (Eggum, 1973). However, important additional information on these compounds can be obtained from studying the tissues and organs in model animals (Hedemann et al., 1999).

5. Objectives and expected achievements

5.1 Grain legumes for mono- and intercropping in organic farming systems

The objectives are:

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

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

5.2 Performance of 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 whether to which extend differences exist between grain legume species and varieties in recovering and utilise P from soils low in available P.

5. 3 Intercropping of grain legumes and cereals: resource use and weed management

The objectives are to:

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

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

5. 4 Plant health in grain legume and cereal crops
The objectives are to:

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

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

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

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

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

6. Description of workpackages including methods

Table 1: Workpackage list

Work-package No	Work package title	Responsi-ble par-ticipant	Budget	Start	End	Deliver-able No
1	Evaluation of potential grain legumes for mono- and intercropping with cereals	BJ	1.4 mill. DKK	April 2000	Decem-ber 2003	1-4
2	Performance of grain legumes and cereals at low K and P levels	MA	0.94 mill. DKK	April 2000	Decem-ber 2003	5-8
3	Intercropping of grain legumes and cereals: resource use and weed management	ESJ	2.16 mill. DKK	February 2001	Decem-ber 2003	9-13
4	Plant health in relation to intercropping and nutrient uptake	ML	1.4 mill DKK	February 2001	Decem-ber 2003	14-16
5	Quality of grain legumes and cereals and isotope analysis	KEBK	0.67 mill DKK	Septem-ber 2001	Decem-ber 2003	17-21

Table 2: Description of workpackages

WP1: Evaluation potential grain legumes for mono- and intercropping with cereals

Workpackage number:	1			
Start date or starting event:	1 April 2001			
Responsible person:	BJ			
Contributing persons:	BJ	JLC	ESJ	PD1

Objectives

To improve the basis for selecting the appropriate species and varieties of legumes and cereal for mono- and intercropping of the grain legumes in organic cropping systems. This will include:

1. Evaluation of available varieties and breeding lines potential for mono- and intercropping of peas, faba beans, narrow-leaf lupins, spring barley, wheat and triticale,
2. to determine yield of grain and biomass, nitrogen uptake and N_2 fixation, crop N balance, of mono-cropped grain legumes species and types on to soil types during three years in organic cropping systems,
3. to evaluate ideotypes of grain legumes with different growth rhythm, total height and branching structure for their qualities for intercropping and weed suppression ability using lupin genotypes as model plants,

Description of work

Task 1 Screening of potential genotypes

A range of varieties and breeding lines of peas, faba beans, narrow-leaf lupin, spring wheat, triticale and barley will in the first year of the project be characterized at Højbakkegaard experimental station at a sandy loam soil. Varieties known from Danish official variety testing and other research programmes will only be included as references. Peas, barley and wheat will have low representation in the screening. Faba bean, lupins and triticale will be represented by a larger number of genotypes. All genotypes will be characterised for plant development, including height during the growing season branching structure, time of flowering and ripening and other special characteristics observed in the course of the experiment and judged relevant for their cultivation in mono- or intercropping in organically cultivated soils. Selected genotypes will be analysed for crude protein in WP5.

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

Cultivars of grain legumes (pea, faba bean and narrow-leaf lupin) will be grown as monocrops in three years at two sites with different soils characteristics (Højbakkegaard, KVL and Jyndevad, DIAS) in the organic rotations on these sites. The experiment will be integrated with the experiment under WP3, Task 1. We will determine the yield and straw production, yield stability over three years, nitrogen uptake from soil and N_2 fixation using ^{15}N methodology and crop N balances will be estbalished. Quality parameters will be determined on selected grain legumes samples in WP5.

Task 3 Ideotypes for intercropping

A set of ideotypes varying in time for the stem elongation, final plant height and branching type has been identified in *Lupinus angustifolius*. Some of these lines possess improved agronomic characters in earliness, stability and yield. They will serve as a set of model plants in the study of the importance of the growth form of the legume for intercropping with cereals and for the competitive ability against weeds. The experiment will be performed at Højbakkegaard experimental station in year 2 and 3 of the project. The influence of time of stem elongation, final height, and degree of branching (in total 5-6 ideotypes) on an intercropped cereal and on the natural weed population will be investigated at one density of barley and lupin.

Deliverables

D1. Recommendations for choice of species and varieties of peas, faba beans lupines and spring barley, wheat and triticale for the mono- and intercropping experiments in the other work packages.
D2. Genotypic characteristic for good intercropping and weed suppressing ability.
D3. Paper on yield variability and N_2 fixation in grain legumes on two soil types.
D4. Paper on grain legume genotypes for intercropping and weed suppression

Milestones
1. Background for selecting genotypes for the experiments in work package 2, 3 and 4. (2001)
2. Recommendations for species and varieties for inter- and monocropping (2003)
3. Recommendations for ideotypes of narrow-leaf lupin for intercropping or weed management (2003)

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

Workpackage number:	2
Start date or starting event:	1 January 2001
Responsable person:	MA
Contributing persons:	MA BJ

Objectives
1. to estimate the effect of low K-status on the production of protein in cereal and grain legume crops on a coarse sandy soil.
2. to quantify the P uptake of different grain legume species, cereals and their intercropped mixtures, and to estimate their performance at low soil P levels.

Description of work
K-experiments:
Task 1.
The investigation is carried out on a coarse sandy soil low in exchangeable K at Jyndevad experimental station (DIAS). Prior to the experiment the K-level will be lowered by means of a grass-clover crop for silage. The following spring barley, pea and lupines representing different levels of protein production will be established at 2-3 different K-fertilisation levels including a treatment with no K application. The effect on dry matter yields, protein content and N_2-fixation using the ^{15}N dilution method is determined.
In order to relate the crop response with the soil K-status, analysis of the different soil K-fractions (exchangeable, nonexchangeable and mineral K) and other relevant soil parameters as texture, pH and cation exchange capacity will be carried out. The effect of the different crops on the soil K fractions will be measured. A set of suitable chemical methods among which is extraction of K with ammonium acetate, boiling nitric acid and cation exchange resins will be used.

In order to evaluate the protein production on a crop rotation scale the effect of the tested crops on a succeeding cereal crop is examined. Dry matter yield and protein content are measured. The work will be carried out in collaboration with a research project (DARCOF, I.10) focusing on catch crops (se collaborative partners). This enables us to examine the combined effect of the "protein" crop and different types of catch crops on the production of protein in a succeeding non-fixing crop.

Task 2
A simple K fertiliser experiment carried out in the organic crop rotation experiment at Jyndevad (Olesen *et al.,* 2000), where the K-status is very low. The plots will be divided into a +K and a –K treatment, and dry matter and protein yields are measured in the cereal and grain legume crops.

P-experiments:
Task 3
The experiment will be carried out at Højbakkegaard experimental station on a loamy soil. It will be established at the experimental unit concerning long time effect of increasing application of N, P and K in cattle slurry and commercial fertiliser on soil quality, fertility and plant nutrition.
The experimental design aims at comparing the crop performance and P uptake at low levels of P. A reference area where P is not limiting will be included. The experiment will be performed in year 2001 and 2002 after the screening of genotypes in work package 1 has revealed which genotypes of pea, faba bean and lupine it will be relevant to use. The soils will be analysed for plant available P. The plants will be analysed for P uptake, biomass production yield and nitrogen. The main effect of plant species and P level on feed quality will be measured. If yield and N content are significantly affected by the P or K level and plant species, feeding quality will also be assessed for these combinations according to WP 5.

Deliverables
D5. Paper on the effect of low K-status on protein production on a coarse sandy soil submitted to an international refereed journal
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
D7. Paper on P uptake of grain legumes and cereals at low P status soil and their growth performance
D8. Papers in national agronomic magazines for information about the results

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 determined (2002)
2. Experiments finished (2003)
3. The pre-crop effect of different cereal and grain legume crops on coarse sandy soil determined. (2003)
4. Characterisation of P uptake capacity of grain legumes and their growth performance at low P status soil (2003)
5. Recommendation for species/genotype choice at low P status soil (2003)

WP3: Intercropping grain legumes and cereals - Resource use, weed management and seed quality

Workpackage number:	3
Start date or starting event:	1 February 2001
Responsable person:	ESJ
Contributing persons:	ESJ PD1 BJ CA VL

Objectives
1. To determine the effects of intercropping grain legumes pea, faba bean and narrow-leaf lupine types and cereals compared to monocrops in organic farming systems on two soil types during three years on grain yield, yield stability, nitrogen use, crop N balance, N availability in the succeeding autumn and the quality of seeds,
2. To determine the use of multiple resources by pea-barley intercrop/weed and monocrop/weed communities, to evaluated the mechanisms of crop-weed competition in intercropping, and
3. To determine the effect of intercropping design and plant density on the weed growth

Description of work
Task 1. Intercropping of grain legumes and cereals on two soil types during three years
Intercrop combinations and monocrops of grain legumes (pea, faba bean, narrow-leaf lupin) and cereals will grown in field plot experiments at two soil types (sandy loam at Højbakkegård Experimental Station (KVL), and a sand soil at Jyndevad (DIAS) during 2001-2003. The grain legume species and types to be used in the experiments will be selected from screenings in 2000 (WP1). The following parameters will be evaluated in the experiments: grain and biomass yield at maturity, yield stability, use of nitrogen sources (soil N and N_2 fixation),crop N balance, nitrogen uptake in a succeeding N-catch crop, and quality parameters in relation to feeding of monogastric animals of grain legume and cereal seeds from inter- and monocrops and of intercropped wheat for breadmaking (WP5). Eventually crops will be monitored for plant diseases.
Task 2. Use of multiple resources by intercrop/weed and monocrop/weed communities
The use of multiple resources will be determined in cereal-grain legume intercrop/weed and monocrop/weed communities at a sandy loam soil at Højbakkegård (KVL). The use of soil N, N_2 fixation, P and K uptake, water and light interception in the crop will be determined in crops communities as influenced by intercrop design.
Task 3. Effect of intercrop design and plant density on weed growth
Competition experiments using different plant densities and intercrop design (additive, replacement), monocrops and a model weed (e.g. white mustard or rape) will be established at Højbakkegård in field experiments. Competition will be evaluated by the dry matter production of crop components and weeds. Crops will be monitored for plant diseases.

Methods
The experimental work will be mainly field experiment in standard plots. The advantages from intercropping will be determined using the land equivalent ratio (Willey, 1979). To determine the use of soil N and N_2 fixation, ^{15}N isotope methods will be employed and elemental analysis-mass spectrometry will be used for determination of total N and ^{15}N. Standard methods will be used determination of P and K. To determine water use we will plan

to determine ^{13}C for water use efficiency. TDR methods will be used for determining the soil water content and the water use of the components in the intercrop will be estimated from the leaf area (LAI 2000). The interception of light in the canopy of crops will be determined by using a line quantum sensor. Isotopic analysis will be carried out under WP5.

Deliverables
D9. Paper on the effects of intercropping grain legumes and cereals at different soil types on various parameters.
D10. Paper on multiple resource use by inter- and monocrop of pea and barley
D11. Paper on the competition for multiple resources between intercrops and weeds
D12. Paper on the effect of intercrop design and plant density on the competition with weeds
D13. Guidelines for intercropping grain legumes and cereals for multiple functions in organic cropping systems.

Milestones
1. Results from field experiments year 1 (ultimo. 2001)
2. Results from field experiments year 2 (ultimo. 2002)
3. Results from field experiments year 3, report and papers (ultimo. 2003)

WP4: Disease resistance in relation to intercropping and nutrient uptake

Workpackage number:	4
Start date or starting event:	1 February 2001
Responsable person:	ML
Contributing persons:	ML PD2

Objectives
Determine how availability of nutrients (N, K and Si) in crops grown on low K soils and inter cropping systems between cereals and legumes under organic farming conditions affects establishment and development of plant diseases and characterise possible mechanisms involved.

Description of work
Tasks
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.
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.
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. gramini*s and pea / *M. pinodes*).
4. Monitoring diseases in field plots described in WP2 and WP3.

Methods
Field trials (2 years) will be performed together with the trials described in WP3. The intercrop and pure stands of barley and pea with or without artificial inoculation (pea with *M. pinodes* and if necessary barley with B. graminis) will be compared. Data on crop development, plant nutritional status (see WP3) and disease progress will be collected. The nutritional status of the crop will be determined by plant tissue analyses and characterised by nutrient contents (e. g. N, P, K, and Si content) and nutrient ratios (e. g. Si/N ratio, K/N ratio).

Based on results of the field trials, controlled experiments will be conducted to study possible effects of intercropping on disease resistance mechanisms. Growth of plants will be manipulated to mimic field conditions in controlled environment. Experiments will involve precise inoculation of host plants, bioassays to determine disease level and advanced light and fluorescence microscopy of fixed material to examine resistance mechanisms. Focus will be on expression of quantitative cellular resistance mechanisms like papilla deposition, unspecific cell death, accumulation of phenolic compounds and the ability to prevent fungal colonisation after infection. Additional genotypes/cultivars of barley and pea will be included to determine possible genotype effects.

Based on results from first year field trials on sandy soils low in K, described in WP2, disease problems related to nutrient uptake (N, K, Si) will be examined under controlled conditions. This will include influence of different levels of K, and ratios between K/N and K/Si, on disease resistance mechanisms. The same methods as mentioned above will be applied. Additional genotypes/cultivars of barley and pea will be included to determine possible genotype effects.

Presence and degree of diseases in field plots in WP2 and WP3 will be scored one or two times during the growing season.

Deliverables

D14.Paper about intercropping and disease resistance
D15.Paper about influence of nutrient uptake on disease resistance
D16. Recommendations of plant characteristics which should be taken into consideration when choosing cultivar or breeding material

Milestones

1. Paper about intercropping and disease resistance (December 2002)
2. Paper about influence of nutrient uptake on disease resistance (May 2003)

WP5: Quality of grain legumes and cereals and isotopic analysis

Workpackage number:	5		
Start date or starting event:	1 October 2001		
Responsable person:	KEBK		
Contributing persons:	KEBK	SB	PA

Objectives

The main objective of this workpackage is to improve our knowledge of the nutritional quality of grain legumes for feed grown under organic farming conditions as monocrops or intercropped and as influenced by types of soil and the nutritional status of the soil and to determine the effect of intercropping on wheat quality parameters for baking

Description of work

The samples for the nutritional evaluation will derive from the experiments in WP 1, 2 and 3. The total number of samples, produced in these work packages, will largely exceed the analytical budget and it will consequently be necessary only to analyse a sub-set of samples for nutritional quality. In total, however, we expect to perform ~200 total nitrogen determinations, ~30 complete chemical, in vitro and ANF evaluations and ~20 evaluations with the rat bioassay.

Tasks

1. Determination of the effect of cultivation system on nutritional quality of grain legumes

Samples of grain legume (peas, faba beans and narrow-leaved lupins) will be selected from WP1 and WP3. A large number of samples from the screening study in WP1 will be selected for total N determination to identify the total variation in nitrogen content. From the samples produced in WP3 we will select samples from the study with intercrop combination and monocrops in a way so that the effect of cropping system and year can be identified. These samples will be analysed for chemical composition, in vitro digestibility and evaluated in vivo by the rat bioassay method.

2. Determination of impact of type of soil and K status of soil on nutritional quality of grain legumes

This investigation will primarily focus on the impact of type of soil (sandy loam vs. coarse sandy soil) and nutritional status of the soil (high and low in K status) on the nutritional quality of grain legumes. The samples will be selected from crops grown under two years on a good quality sandy loam at Højbakkegaard experimental station, and on a poor quality coarse sandy soil at Jyndevad experimental station (WP2). Samples grown under contrasting K status at Jyndevad experimental station will further be used to identify the impact of nutritional status of the soil on nutritional quality. These samples will be analysed for chemical composition, in vitro digestibility and evaluated in vivo by the rat bioassay method.

3. Identification of possible antinutritional factors in grain legumes

The samples will be those used for chemical and nutritional characterisations in tasks 1 and 2. Grain legume samples of peas and faba beans will be further evaluated for the content of protease inhibitors and tannins and correlated to digestibility and biological value of the grains obtained from the rat bioassay method.

4. Quality of wheat for bread

Selected wheat samples from the intercropping experiments will be evaluated for baking quality parameters

5. Stable isotopes

Samples will be analysed for ^{15}N and ^{13}C according to the experimental plan using a elemental analyser coupled online to an isotope ratio mass spectrometer in the CONFIRM center at Risø National Laboratory.

Methods

The content of ash, protein, fat, amino acids, carbohydrates including NDO, starch and fibre components, protease inhibitors, tannins and in vitro methods for the determination of digestibility at ileum and in faeces will be analysed by methods that are well established at the Danish Institute of Agricultural Sciences. Protein quality, including true protein digestibility (TD), biological value (BV), and net protein utilization (NPU) will be determined of protein sources and complete diets by using a standardized rat bioassay.

Deliverables

D17. Report on the variation in total nitrogen from the screening study
D18. Paper on the effect of cultivation system on the nutritional quality of grain legumes
D19. Paper on the impact of type of soil and its K status of soil on the nutritional quality of grain legumes
D20. Identification of possible antinutritional factors in peas and faba beans
D21. Stable isotope ratios determined for WP1, WP2, WP3.

Milestones

1. Evaluation of variation in total nitrogen from the screening study (2002)
2. Evaluation of impact of cultivation system on the nutritional quality of grain legumes (2003)
3. Evaluation of impact of type of soil and its K-status on the nutritional quality of grain legumes (2003)
4. Identification of possible antinutritional factors in grain legumes grown under organic farming conditions (2003)
5. Evaluation of baking quality of wheat (2003)
6. Stable isotope ratios determined for WP1, WP2, and WP3 (primo 2002, primo and ultimo 2003)

7. Implementation and time schedule

Table 3: Deliverables list

Deliver-able No	Deliverable title	Delivery date	Meeting	Nature
D1	Recommendations for choice of species and varieties of GL and cereals for experiments in the other work packages.	Jan 2001		O
D2	Genotypic characteristic for good intercropping and weed suppressing ability.	Dec 2003		R
D3	Paper on yield variability and N_2 fixation in grain legumes on two soil types.	Dec 2003		Pu
D4	Paper on grain legume genotypes for intercropping and weed suppression	Dec 2003		Pu
D5	Paper on the effect of low K-status on protein production on a coarse sandy soil submitted to an international refereed journal	Dec 2003		Pu
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	Dec 2003		Pu
D7	Paper on P uptake of grain legumes and cereals at low P status soil and their growth performance	Mar 2003		Pu
D8	Papers in national agronomic magazines for information about the results	Mar 2002		Pu
D9	Paper on the effects of intercropping grain legumes and cereals at different soil types on various parameters.	Dec 2003		Pu
D10	Paper on multiple resource use by inter- and monocrop of pea and barley	Dec 2003		Pu
D11	Paper on the competition for multiple resources between intercrops and weeds	Dec 2003		Pu
D12	Paper on the effect of intercrop design and plant density on the competition with weeds	Dec 2003		Pu
D13	Guidelines for intercropping grain legumes and cereals for multiple functions in organic cropping systems	Dec 2003		O
D14	Paper about intercropping and disease resistance	Jan 2003		Pu
D15	Paper about influence of nutrient uptake on disease resistance	Dec 2003		Pu
D16	Recommendations of plant characteristics which should be taken into consideration when choosing cultivar or breeding material	Dec 2003		O
D17	Report on the variation in total nitrogen from the screening study	Dec 2003		Re
D18	Paper on the effect of cultivation system on the nutritional quality of grain legumes	Dec 2003		Pu
D19	Paper on the impact of type of soil and its K status of soil on the nutritional quality of grain legumes	Dec 2003		Pu
D20	Identification of possible antinutritional factors in peas and faba beans	Dec 2003		Pu
D21	Stable isotope ratios determined for WP1, WP2, WP3	Jan 2002 Jan 2003 Dec 2003		O O O

8. Collaborative partners

National

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

The project will also be co-ordinated with the on-going ph.d.-project (HHN) on the intercropping of pea and barley in relation to N-dynamics in organic cropping systems, funded by DARCOF.

International

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

In his position of member of the scientific committee of The European Association of Grain Legume Research (AEP), ESJ has strong links with European scientists within all disciplines of grain legume research.

KVL members of the research team has submitted two proposals for the 5th Framework Programme with KVL as the coordinator:

- "Intercropping in European organic farming systems" with 6 European partners from the Swedish University of Agricultural Science, University of Kassel, Witzenhausen (D), University of Wageningen (NL), Ecole Superiore Agriculture, Angers (F), University of Reading (UK), University of Warmia and Mazury (P), and
- A project on the development of lupines for organic farming in the EU with participants from Poland, Germany, Portugal, UK and Ireland. KVL collaborate with national and international institutions regarding projects on development of lupins.

KVL participates in other proposals for the 5FP within organic farming, e.g. the proposal SUSTAIN, an European innovation network for integrated and organic farming systems.

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.

9. Budget (KKR)

Institution/(group)	2000	2001	2002	2003	Total
KVL (ESJ)	**WP3,** WP1#				
Salary (scientific)		330	371	346	1047
Salary (technical)		173	178	138	489
Operation		140	140	100	380
Overhead		128	138	118	384
Total		772	827	702	2300
KVL (BJ)	**WP1**, WP2, WP3				
Salary (scientific)	99	396	231	126	853
Salary (technical)	24	119	95	48	286
Operation	15	40	40	15	110
Overhead	28	111	73	39	251
Total	166	666	439	228	1500
Risø (ML)	**WP4**, WP1-3				
Salary (scientific)		401	403	206	1012
Salary (technical)		47	47	24	118
Operation		60	50	10	120
Overhead		100	100	51	250
Total		609	601	291	1500
Risø (PA)	WP1-3				
Salary (scientific)		4	13	18	35
Salary (technical)		5	25	28	58
Operation		8	30	35	73
Overhead		3	14	16	33
Total		20	82	98	200
DIAS (MA)	WP2				
Salary (scientific)		107	112	129	348
Salary (technical)		40	42	6	88
Operation	27	159	155	55	396
Overhead	5	61	62	39	167
Total	33	367	371	229	1000
DIAS (KEBK)	**WP5,** WP1-3				
Salary (scientific)		37	38	60	135
Salary (technical)		44	70	70	184
Operation		22	43	33	98
Overhead		20	30	33	83
Total		123	181	196	500
Project I.5 Total	199	2557	2501	1743	7000

Indicate which work packages that the group is involved in.

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Jensen, E.S. 1996. Grain yield, symbiotic N_2 fixation and interspecific competition for inorganic N in pea-barley intercrops. Plant and Soil 182, 25-38.

Jensen, E.S. 1997. The role of grain legume N_2 fixation in the nitrogen cycling of temperate cropping systems. D.Sc. Thesis, Report R-888(EN), 86 p. Risø, Roskilde.

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Josefsen, A.B., Sandbech, H., Kærgård, N., Revsbech, K. & Bichel, S. 1999. Ecological scenarios for Denmark. A report from the interdisciplinary group in the committee for pesticides, Danish Environmental Protection Agency (in Danish).

Lampkin, N. 1990. Organic Farming, Framing Press Books, Ipswich, UK

Li, Y. & Barber,S.A. 1992. Calculating changes of soil rhizosphere soil pH and soil solution phosphorus uptake. Communication in Soil Science and Plant Analysis. 22: 9-10, 955-973

Liebman, M. and Dyck, E. 1993. Crop rotation and intercropping strategies for weed management. Ecological applications 3, 92-122.

Nemcová, R., Borba, A., Gancar´coková, S., Herich, R. and Guba, P. (1999). Study of the effect of *Lactobacillus paracasei* and fructooligosaccharides on the faecal microflora in weanling piglets. Berl. Münch. Tierärztl. Wschr., 112: 225-228.

Ntahimpera N, Ellis MA, Wilson LL, Madden LV. 1998. Effects of a cover crop on splash dispersal of *colletotrichum acutatum* conidia. Phytopathology 88: 536-543

Norholt , H. 1997. Samfundsøkonomiske konsekvenser af en omlægning til økologisk jordbrug. Report. KVL, Copenhagen.

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Pahl, H. 1999. Economic constratints for garin legume production and utilisation in Europe. Supplements to the proceedings of the 3rd European Confrence on Grain Legumes. pp. 4-8. AEP, Paris.

Rasmussen, I. A. 1999 Plantebeskyttelse i økologisk jordbrug - rapport fra en workshop. 84 p, FØJO, Tjele.

Sander JF, Heitefuss R. 1998. Susceptibility to *erysiphe graminis* f. Sp. *tritici* and phenolic acid content of wheat as influenced by different levels of nitrogen fertilization. Journal of Phytopathology 146: 495-507

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Trenbath BR. 1993. Intercropping for the management of pests and diseases. Field Crops Research 34: 381-405

Trolldenier G. 1983. Wechselwirkungen zwischen meltaubefall, kaliumernahung und fungizideinsatz auf den ertrag zweier sommergerstensorten. Phytopathologische Zeitschrift 104: 337-344

Vandermeer, J. 1989. The Ecology of Intercropping CambridgeUniv. Press

Vandermeer, J. and Perfecto, I. 1995. Breakfast of biodiversity: the truth about rain forest destruction. Food First Books, Oakland. 185 pp.

Wassermann, V.D., 1986. Field response to P and K fertilizers of *Lupinus albus* cv. Kiev and *L. angustifolius* cv. Unicrop. South African Journal of Plant and Soil. 3, 193-197.

Willey, R.W. 1979a. Intercropping – its importance and research needs. Part 1. Competition and yield advantage. Field Crop Abstracts 32, 1-10.

Wiseman, J. and Cole, D. J. A. 1988. European legumes in diets for non-ruminants. In *Recent Advances in Animal Nutrition-1988*, pp [W. Haresign and D. J. A. Cole ed(s)]. London: Butterworths.

Appendix:

CV for Erik Steen Jensen (co-ordinator and manager of WP3)

Personal data:

Name: Erik Steen Jensen
Born: 29 May 1955
Address: Brovej 19, Veddelev, DK-4000 Roskilde
Phone: +4546757415.

Education:

M.Sc. (1980), Ph.D (1986) and D.Sc. (1997) from The Royal Veterinary and Agricultural University of Copenhagen.

Present occupation (since 1998):

Professor, Agroecology, Department of Agricultural Sciences, The Royal Veterinary and Agricultural University, Agrovej 10, DK-2630 Taastrup, Phone:+4535283517, Fax: 35282175, E-mail: esj@kvl.dk

Previous occupations:

Oct. 91-Aug. 98 - Senior scientist, Head of research group on: Nitrogen and soil organic matter turnover in agro-ecosystems, Plant Biology and Biogeochemistry Department, Risø National Laboratory. DK-4000 Roskilde. Aug 80 – Oct. 91 Scientist at Risø National Laboratory

Research activities and interests:

Plant production in organic farming systems, symbiotic nitrogen fixation, intercropping, nitrogen and soil organic matter turnover in agro-ecosystems with special emphasis on crop residues, farmyard manure, organic waste, *Rhizobium* ecology, stable isotope methodology. Supervisor for 12 M.Sc. and 9 Ph.D projects

Publications and teaching:

62 research papers in international journals with a referee system
55 research papers in books and proceedings
40 popular papers, reports and theses.

Scientific appointments:

Referee for 13 international journals and member of the Editorial board of Plant and Soil
IAEA/FAO expert on the use of stable isotopes in agricultural and environmental research
Member of the Danish Agricultural and Veterinary Research Council and the Board Of The Danish Institute of Agricultural Sciences. President (1999-2001) of the European Association of Grain Legume Research (AEP, Paris) and President of The Centre for Ecology and Environment at KVL.

Five relevant publications

Jensen, E.S. 1986. Intercropping field bean with spring wheat. Vorträge für Pflanzenzuchtung 11, 67-75.

Jensen, E.S. 1996. Rhizodeposition of N by pea and barley and its effect on soil N dynamics. Soil Biology and Biochemistry 28: 65-71.

Jensen, E.S. 1996. Barley uptake of N deposited in the rhizosphere of associated field pea. Soil Biology and Biochemistry 28, 159-168.

Jensen, E.S. 1996. Nitrogen acquisition by pea and barley and the effect of their crop residues on available nitrogen for subsequent crops. Biology and Fertility of Soils 23: 459-464.

Jensen, E.S. 1996. Symbiotic N_2-fixation and interspecific competition for inorganic N in pea-barley intercrops. Plant and Soil 182: 13-23.

Short CV for Christian Andreasen (participant WP3)

PhD, Associate Professor.

More than 15 years experience in botany and weed science. Main research interest has been vegetation ecology, flora changes, method for flora analyses (botanical and statistical analysis, use of image analysis) and methods for mapping weeds on arable fields, but he has also worked on a wide range of other projects concering weed biology, competition studies and weed control. Experience in leading research.

Selected publications

Andreasen C. (1990) The occurrence of weed species in Danish arable fields. Ph.D. thesis, Department of Agricultural Sciences, The Royal Veterinary and Agricultural University, Frederiksberg, Copenhagen. 125 pp.

Andreasen C., J.C. Streibig & H. Haas (1991) Soil properties affecting 37 weed species in Denmark. *Weed Research* 31, 181–187.

Andreasen C., J.E. Jensen & J.C. Streibig (1992) Weed communities described by multivariate analysis. *Proceedings of the First International Weed Control Congress.* Melbourne, Australia. Vol. 2. 50-54.

Andreasen C., H. Stryhn & J.C. Streibig (1996) Decline of the flora on Danish arable fields. *Journal of Applied Ecology* 33, 619-626.

Andreasen C., M. Rudemo & S. Sevestre (1997) Assessment of weed density at an early stage by use of image processing. *Weed Research* 37 (1), 5-18.

Short CV for Vibeke Langer (particpant WP3)

Personal data

Born Dec. 15, 1953 in Copenhagen
Home: Ibsgården 72B, 4000 Roskilde, 4632 1377
Office: Agrovej 10, 2630 Taastrup, 3528 2383, vl@kvl.dk

Education

1980	M.Sc. (Cand. hort.) in Horticultural science.
1995	Ph.D. from Section Zoology, Department of Ecology and Molecular Biology, The royal Veterinary and Agricultural University (KVL). Minor in Crop Science. Thesis: "Within field diversification. A study of crop yield, insect pests and natural enemies in a cabbage-clover system."

Employment

1980-86	Advisor in The Danish Fruit Growers organisation (Dansk Erhvervsfrugtavl). Special tasks: pest management and intensive planting systems.
1987-88	Project leader on the project "Plant protection in ecological vegetable production". University of Aalborg. Funded by The Danish Veterinary and Agricultural Research Council.
1989-92	Scholar (kandidatstipendiat) at Section of Zoology, Department of Ecology and Molecular Biology, KVL.
1993-94	Researcher on the project "Development of simulation models as basis of decision support systems in integrated vegetable production". Funded by Danish Ministry of Agriculture. Section of Zoology, KVL.
1995	Lecturer (amanuensis) at Agroecology Group, Department of Agricultural Science, KVL.

Relevant publications

Langer, V. 2000. Farm level changes with conversion to organic agriculture in a region of intensive agriculture. American Journal of Alternative Agriculture. (Accepted)

Langer, V. 2000. Clover/grass ley and short rotation coppice hedges as reservoirs for parasitoids of cereal aphids in organic agriculture. Agriculture, Ecosystems and Environment. (Accepted)

Langer, V. 1998. Effects of conversion to organic farming on Danish agricultural landscapes. In: P. Agger, R. Bjerregaard, J. Brandt (eds.), Landscape ecology and the dynamics of agricultural landscapes. Landskabsøkologiske skrifter 11, 311-319

Langer, V. 1996. Within field diversification. A study of crop yield, insect pests and natural enemies in a cabbage-clover system. Ph.D. Thesis. Inst. for Økologi og Molekylærbiologi, KVL. 78 pp.

Langer V. 1996. Insect-crop interactions in a diversified cropping system: parasitism by *Aleochara bilineata* and *Tryblographa rapae* of the cabbage root fly, *Delia radicum*, on cabbage in the presence of white clover. Entomologia Experimentalis et Applicata 80, 365-374

Short CV for Henrik Hauggaard-Nielsen (participant WP3)

Born 28 July 1968

Education:

MSc in plant nutrition and soil fertility, April 1997.

Employment:

Ph.D. student, Dept. Plant Biology and Biochemistry, Risø National Laboratory. PBK-309. 4000 Roskilde. Phone. 4677 4156, Fax: 4677 4160, e-mail henrik.hauggaard-nielsen@risoe.dk.

Research activities:

Competition, ressource use and nitrogen dynamics, annual mulitpsecies crops for organic farming systems. (Ph.D project funded by DARCOF)

Publications:

Hauggaard-Nielsen H. and Jensen E. S. (1999). Genotype effects in relation to pea and barley performance in intercropping systems. Field Crops Research. In prep.

Hauggaard-Nielsen H., Neergaard A. de, Jensen L. S. and Magid J. (1998) A field study of nitrogen dynamics and spring barley growth as affected by the quality of incorporated residues from white clover and ryegrass. Plant and Soil 203: 91-101.

Jensen L. S., Hauggaard-Nielsen H., Eriksen J., Mueller T and Magid J. (1999). Modelling carbon and nitrogen turnover in soil and crop growth after incorporation og clover-grass pastures – do we know the critical parameters? Ecological Modelling. In prep.

Jensen L. S., Hauggaard-Nielsen H., Neergaard A. de and Magid J. (199?) Temporal variation of soil surface CO2 flux, following incorporation of various clover-grass pastures - An analysis by simulation models. Soil Biology & Biochemistry In prep.

Neergaard A. de, Hauggaard-Nielsen H., Jensen L. S., and Magid J. (1999). Decomposition of whiteclover (Trifolium repens) and ryegrass (Lolium perenne) components related to quality parameters. An incubation study of Carbon and Nitrogen dynamics. Plant and Soil. Accepted subject to revision

Short CV. for Bjarne Jørnsgård (manager of WP1)

Born 1961
Address:
Egøjebyvej 12, 4600 Køge.
Private phone: +45 56 21 41 21

Experience
10 years experience in crop physiology, competition studies and related topics.
Extensive research on lupin since 1994.
Current position
Project work on an EU programme on "Creation of varieties and technologies for increasing production and utilisation of high quality protein from the white lupin in Europe".

1997- Project work on a development program of organic grown lup ins.

1995- Project Manager of a joint venture project: Development of lupins as a protein crop for animal, human and industrial use in Denmark, between The Royal Veterinary and Agricultural University, Institute of Soil Science, Novo Nordisk Ltd, The Danish Institute of Plant and Soil Science and National Institute of Animal Science

1991-95 Ph.D. studies on crop physiology at the Royal Veterinary and Agricultural University, Dept. of Crop Science.

1991 Project work on introduction of new and alternative crops at The Royal Veterinary and Agricultural University .

1989-91 Project work on risks assessment and competitive ability of transgenic plants at The Royal Veterinary and Agricultural University.

Education

1989 Master in Agronomy, KVL, Copenhagen. Specialization in plant science, economy and cattle production.

1988 Diploma Ingenieur Agronome, Montpelier. Specialization in Mediterranean Agriculture at ENSAM.. (Fransk master i med speciale i middelhavslandbrug 1988).

Selected publications:

Fredshavn J., B. Jørnsgård and J.C. Streibig, 1990. Assessment of crop weed competition under greenhouse and field condition. Proceedings of the EWRS Symposium in Helsinki, Finland, 1990: 239-246.
Jørnsgård, B.,K. Rasmussen, J. Hill and J.L. Christiansen. 1996. Influence of nitrogene on competition between cereals and their natural weed populations. Weed Research. 36.461-470.
Jørnsgård B.and Christiansen J.L. 1998. Influence of water stress at different growth stages on canopy structure in *Lupinus angustifolius.* In Proceedings of the Manipulation of Crop Architecture Conference. Rothamsted, England. pp 4.
Jørnsgård, B., H. Agerskov, S. Raza and J. L. Christiansen. A rapid screening test for calciumtolerance in lupin. soils.lupin.The IXth International Lupin Conference. Klink/Müritz. Germany. In press.
Rasa, S., J.L. Christiansen, B. Jørnsgård and R. Ortiz. 1999. Resistance to *Fusarium oxysporum* f.sp. Lupini Egyptian white lupin landraces. Euphytica. (in press).

Short CV for Jørgen L. Christiansen (participant WP1)

Associate Professor, Institute for Agricultural Science, The Royal Veterinary and Agricultural University.
More than 25 years experience in plant breeding and plant physiology.
Extensive research on lupin since 1993.

Selected Publications:

Christiansen, J.L., B. Jørnsgård, S. Buskov and C.E. Olsen. 1997. Effect of drought stress on content and composition of seed alkaloids in narrow-leafed lupin *Lupinus angustifolius*. European Journal of Agriculture. 7: 307-314.
Christiansen, J.L., S. Raza & R. Ortiz. 1999. White lupin germplasm collection and preliminary in situ diversity assessment in Egypt. Genetic Resources and Crop Evolution.46.169-174.
Christiansen J.L. B. Jørnsgård, G. Holm and M. Clausen. 1997. Influence of temperature and sowingdate on canopy development and yield stability in a determinate and an indeterminate variety of *Lupinus angustifolius* L. Proceedings of conference on Lupin in Modern Agriculture. Olszyn, Poland. 1: 205-212.

Short CV for Margrethe Askegaard (manager of WP2)

Name	Margrethe Askegaard
Date of birth	January 2, 1955
Address	Hobro Landevej 62, DK-8830 Tjele, Denmark
Employment	Danish Institute of Agricultural Science (DIAS)

	Dept. of Crop Physiology and Soil Science Research Centre Foulum P.O. Box 50, DK-8830 Tjele
Education	Royal Veterinary and Agricultural University, Copenhagen, Denmark M.Sc. (Agronomy, plant husbandry), 1980.
Employment record	
1997-date	Scientist, DIAS, Dept. of Crop Physiology and Soil Science
1993-1997	Scientist, Danish Institute of Plant and Soil Science, Dept. of Soil Science
1983-1993	Advisor, Agricultural Extension Service.
1980-1983:	Instructor, Agricultural Schools.
Research Activities	
1997-date	Project leader of a project on nutrient management in an organic dairy crop rotation.
1997-date	Participating project leader of a project on organic crop rotations for grain production
1996-date	Project leader of a project on availability and utilisation of potassium, phosphor and sulphur in the soil-plant system in organic plant production.
1996-date	Ph.D. project on potassium dynamics in organic farming as main objective.
1994-1997	Project leader of a project on plant production, nutrient management and crop protection on organic dairy farms.
1993-1994	Participant in a project on plant production, nutrient management and crop protection on organic dairy farms.
Relevant publications	Askegaard, M.& Eriksen, J. 2000. Potassium leaching and retention in an organic crop rotation on loamy sand (submitted to Soil Use and Management). Askegaard, M., Rasmussen, I.A. & Olesen, J.E. 1999. Agronomic considerations and dilemmas in the Danish crop rotation experiment. In: Olesen, J.E., Eltun, R., Gooding, M.J., Jensen, E.S. & Köpke, U. (Eds) Designing and testing crop rotations for organic farming. DARCOF Report no. 1, 63-69. Askegaard, M., Eriksen, J., Søegaard, K. & Holm, S. 1999. Nutrient management and plant production in four organic dairy farming systems In: Olesen, J.E., Eltun, R., Gooding, M.J., Jensen, E.S. & Köpke, U. (Eds) Designing and testing crop rotations for organic farming. DARCOF Report no. 1, 257-265. Eriksen, J., Askegaard, M. & Kristensen, K. 1999. Nitrate Leaching in an organic dairy/crop rotation as affected by organic manure type, livestock density and crop. Soil Use and Management, 15, 176-182. Olesen, J.E., Askegaard, M.A. & Rasmussen, I.A. Design of an organic farming crop rotation experiment serving multiple purposes (submitted to Acta Agriculturae Scandinavica, Section B, Soil and Plant Science)

Short CV for Michael Lyngkjær (Manager of WP4)

Personal data:

Name: Michael Foged Lyngkjær
Born: 8 August 1963
Address: Maglehøjvej 23, Varpelev, DK-4672 Klippinge
Phone: +4556578298.

Education:

M.Sc. (1992) and Ph.D (1996) from The Royal Veterinary and Agricultural University of Copenhagen.

Present occupation (since January 1999):

Research scientist, at Department of Plant Biology and Biogeochemistry, Risø National Laboratory, Postbox 49, DK-4000 Roskilde, Phone: +4546774133, Fax: +4546774122, E-mail: m.lyngkjaer@risoe.dk

Previous occupations:

Jan. 97- Jan. 99 Postdoc. at Institute of Grassland and Environmental Research, UK. Receiving a Postdoc scholarship from the Danish Research Council.
Feb. 96 - Jan. 97 Postdoc. at Environmental Science and Technology Department, Risø National Laboratory, DK.

Research activities:

Plant Pathology: Physiological, cellular and biochemical basis of disease resistance mainly in Gramineae to obligate biotrophic fungi, particularly *Blumeria graminis* and necrotrophic fungi, particular *Mycosphaerella graminicola.*

Publications and teaching:

7 research papers in international journals with a referee system
5 research papers in books and proceedings
13 Abstracts etc.

Comments

Membership of learned societies: Danish Society for Plant Pathology.
British Society for Plant Pathology
Chairman of the mlo- resistance subgroup under EU COST Action 817 (1995-1997).

Five recent and relevant publications

Lyngkjær MF, Carver TLW, Zeyen RJ (1997): Suppression of resistance to *Erysiphe graminis* f.sp. *hordei* conferred by the *mlo5* barley powdery mildew resistance gene. **Physiological and Molecular Plant Pathology** 50:17-36.
Lyngkjær MF, Østergård H. (1998): Interaction between powdery mildew and barley with mlo5 mildew resistance. **Plant Pathology** 47: 252-258.
Lyngkjær MF, Carver TLW (1999): Induced accessibility and inaccessibility in barley epidermal cells by a compatible *Blumeria graminis* f.sp. *hordei* isolate. **Physiological and Molecular Plant Pathology** 55:151-162.
Lyngkjær MF, Carver TLW (1999): Modification of *mlo5* resistance to *Blumeria graminis* attack in barley as a consequence of induced accessibility and inaccessibility. **Physiological and Molecular Plant Pathology** 55:163-174.
Lyngkjær MF, Carver TLW (2000): Conditioning of cellular defence responses to powdery mildew in cereal leaves by prior attack. **Molecular Plant Pathology** 1: 41-50.

Short CV for Knud Erik Bach Knudsen (Manager of WP5)

Personal data:

Born June 10, 1952, Stauning, Denmark

Education:

1977 M.Sc. in agronomy (Nutrition), Royal Veterinary and Agricultural University, Copenhagen
1980 Ph.D. (Lic. agro.), Royal Veterinary and Agricultural University, Copenhagen

Employment:

1974-1975 Scholarship, Royal Veterinary and Agricultural University, Dept. of Plant Nutrition
1977-1980 Research grant, Royal Veterinary and Agricultural University, Dept. of Animal Physiology
1980-1983 Researcher, Carlsberg Research Laboratory, Dept. of Biotechnology
1983-1986 Senior research grant, Royal Veterinary and Agricultural University, Dept. of Animal Physiology
1986-1991 Research scientist, National Institute of Animal Science, Dept. of Animal Physiology and Biochemistry
1992-1998 Senior scientist, Danish Institute of Agricultural Sciences, Dept. of Animal Nutrition and Physiology
1998- Head of Research Unit, Danish Institute of Agricultural Sciences, Dept. of Animal Nutrition and Physiology

Studies abroad:

1984 Visiting scientist, Swedish Agricultural University, 1984
1987-1988 Visiting scientist, USDA-Human Nutrition Research Center, Nutrient Composition Laboratory, Beltsville, MD.

Research:

My research is primarily related to carbohydrates and is concentrated on the following main areas: (1) development and implementation of analytical methods for the determination of carbohydrate components in food and feed, (2) studies of breakdown, absorption, metabolism and physiological effects of the various carbohydrates in the gastrointestinal tract, (3) the role of the various carbohydrates on digestive disturbances and establishment of parasites in pigs, and (4) the relationship between the metabolism of carbohydrates in the large intestine and the metabolisms of cell wall-associated components. Most of my research is done in collaboration with national, Nordic and European research groups. I am board member of the Nutrition Society and member of the Editorial Board in Archives of Animal Nutrition and Animal Feed Science and Technology. I am supervisor for Master and Ph.D. students, member of the examiner corps at the Royal Veterinary and Agricultural University and have been the official opponent at Ph.D. and doctor theses in Denmark and abroad.

Key references

Bach Knudsen, K. E. (1997). Carbohydrate and lignin contents of plant materials used in animal nutrition. Animal Feed Science and Technology **67**, 319-338.
Bach Knudsen, K. E., H. N. Johansen and L. V. Glitsø (1997). Methods for analysis of dietary fibre - advantage and limitations. Journal of Animal and Feed Sciences **6**, 185-206.
Canibe, N., K. E. Bach Knudsen and B. O. Eggum (1996). Digestibility and nitrogen balance in rats given dried and toasted peas of different years of harvest. Journal of Food and Agriculture **73**, 21-33.
Canibe, N. and K. E. Bach Knudsen (1997). Digestibility of dried and toasted peas in pigs 1. Ileal and faecal digestibilities of carbohydrates. Animal Feed Science and Technology **64**, 293-310.
Gonzalez, E, K. E. Bach Knudsen, N. Canibe, C. Huyghe, P. Rømer and B. Jørnsgård (1999). Chemical and nutritional characterisation of blue (*Lupinus angustifolius* L.) and white lupins (*L. albus* L.). In *Lupin - An Ancient Crop for the New Millenium*, pp 113-114, (C. Wink and M. Wink eds.). Book of Abstracts 9th International Lupin Conference: Romneya-Verlag, Dossenheim, Germany.

Short CV for Sigurd Boisen (participant WP5)

Born 17th January 1946 in Skodborg, Denmark. Cand scient in Biochemistry from University of Copenhagen in 1974. Teacher in plant physiology, chemistry and biochemistry at University of Copenhagen from 1974 to 1978.

Research scientist at Technical University, Lyngby from 1978 to 1980. Research scientist at National Institute of Animal Science (NIAS), Copenhagen and later Danish Institute of Animal Science (DIAS), Research Centre Foulum from 1980 to 1992. Senior Research scientist at DIAS - later changed to Danish Institute of Agricultural Sciences (DIAS) from 1992 to now. From 1994 to 1995 a one-year sabbatical stay at Monogastric Research Centre, Massey University, Palmerston North, New Zealand.

Recent publications (selected):

Boisen, S. 1997. Ideal protein - and its suitability to characterize protein quality in pig feeds -A review. Acta Agric. Scand., Sect. A, Animal Sci. 47, 31-38.

Boisen, S. & Fernandez, J.A. 1997. Prediction of the total tract digestibility of energy in feedstuffs and pig diets by in vitro analyses. Anim Feed Sci. Technol. 68, 277-286.

Boisen, S. 1998. A new protein evaluation system for pigs and its practical application. Acta Agric. Scand., Sect. A, Animal Sci. 48, 1-11.

Boisen, S. & Verstegen, M.W. A. 1998. Evaluation of feedstuffs and pig diets. Energy or nutrient based evaluation systems? 2. Proposal for a new nutrient based evaluation system. Acta Agric. Scand., Sect. A, Anim. Sci. 48, 95-102.

Hedemann, M.S., Welham, T., Boisen, S., Canibe, N., Bilham, L. & Domoney, C. 1999. Studies on the biological responses of rats to trypsin inhibitors using near-isogenic lines of Pisum sativum L. (pea). J. Sci. Food Agric. 79, 1647-1653.

Short CV for Per Ambus (participant WP5)

Personal data

Name and address: Per Ambus, Rolighedsvej 5, DK-4320 Lejre

Date of birth: 8 November, 1959

Citizenship and marital status: Danish. Married to Hanna Sigga Madslund. Two children.

Education

1987 M.Sc., Department of General Microbiology, Copenhagen Univ. (Denitrification in Subsoils).

1992 Ph.D., Department of Population Biology, Copenhagen Univ. (Denitrification in Riparian Soils).

Has completed courses in HPLC and ion chromatography, health physics, hazardous waste and radio isotope training, project management and training in stable isotope ratio mass spectrometry

Present occupation

Senior Reseach Scientist. Plant Ecosystems and Nutrient Cycling, Plant Biology and Biogeochemistry Department (PBK-309), Risø National Laboratory, DK-4000 Roskilde.

Tel: (+45) 4677 4152. Fax: (+45) 4677 4160. e-mail: per.ambus@risoe.dk ; www: http://www.risoe.dk/pbk/ple

Research activities

Biogeochemical cycling of C and N; denitrification; N_2O and CH_4 emissions from soil; soil N mineralization-immobilization; turnover of organic residues in soil; stable isotope techniques. Principal investigator in multidisciplinary Centre for Continuous Flow Isotope Ratio Mass Spectrometry (CONFIRM).

Professional experience

1988-1990 (18 mo) Graduate student. Departm. Population Biol., Cphgn Univ.

1989 (1½ mo) Visiting graduate. Southeast Watershed Res. Lab. (USDA), Georgia, USA.

1991-1993 (36 mo) Postdoc. fellow. Departm. Population Biol., Cphgn Univ.

1993-1994 and 1996-present Reseach and Senior Research Scientist, Risø National Laboratory.

1995-1996 (24 mo) Visiting Research Associate. Kellogg Biol. St., MSU, USA.

Professional appointments

Member of Inter-Nordic Workshop on Biomonitoring of Soil Biological Processes and Epiphytic Lichens; Coordinator: Joint Field Experiment on N_2O flux measurement methods within EC STEP project; Member of US Trace Gas Network Group; Reviewer on several international journals, reports and bookchapters. Teaching and supervising experience at graduate and post-graduate levels. Has received four major grants as principal investigator during 1991-1997.

Five selected peer reviewed publications

Ambus, P. and G.P. Robertson. 1999. Fluxes of CH_4 and N_2O from Aspen stands grown under ambient and twice-ambient CO_2. Plant Soil. 209: 1-8.

Ambus, P. 1998. Nitrous oxide production by denitrification and nitrification in temperate forest, grassland, and agricultural soils. Eur. J. Soil Sc. 49: 495-502.

Ambus, P. and Robertson, G.P. 1998. Automated near-continuous measurement of carbon dioxide and nitrous oxide fluxes from soil. Soil Sci. Soc. Am. J. 62:394-400.

Ambus, P. and Jensen, E.S. 1997. Nitrogen mineralization and denitrification as influenced by crop residue particle size. Plant and Soil. 197:261-270.

Ambus, P., Mosier, A., and Christensen, S. 1992. Nitrogen turnover rates in a riparian fen determined by ^{15}N dilution. Biology and Fertility of Soils. 14:230-236.

Short CV for Poul Flengmark (Project consultant)

1. **Date of Birth:** 29 12 38
2. **Nationality:** Danish
3. **Civil Status:** Married
4. **Education:**

Name of Institution: Agricultural University, Copenhagen, Denmark, Date of completion: May 1966, Degree of Diploma: M. Sc. Agriculture

7. **Membership of Professional Bodies:**

Nordiske Jordbrugsforskeres Forening (NJF), Pajbjergfonden-Plant Breeding (member of the committee), Nordic Genebank (work group), Min. of Agriculture: Scientific Board for Non-Food Crops, DJF: Member of Comittee for Central Lab.

8. **Other Skills:** Head of Department 1983-1995
9. **Present Position:** Scientist, research group Crop Ecology and Product Quality
10. **Key Qualifications:**

15 years of experience with official Danish variety testing (1969-1983), especially root crops, legumes and oil seed crops. DUS-testing and Value testing. 12 years of leadership of a scientific Department on grass seed, oilseed crops and legumes, together with cereal research , bee pollination and bee disease questions. -active in scientific research from 1969-2000 including partnership in EU projects and Concerted Actions. Several lectures in own organisation and in agricultural organisations.

Publications

40 articles (short communications) in Danish Journal for Plant Culture. 16 articles in Danish and in international journals. 5 articles in agricultural journals.