Danish Research Centre
for Organic Farming

Midterm Status Report 2003 and Application for Continuation in 2004

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1. *Research program*

Research in organic farming 2000-2005 (DARCOF II)

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2. *Project title and number*

FØJO I-4: NItrogen MAnagement and cropping methods for enhanced Bread wheat production (NIMAB)

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6. *Project period (month, year)*

Start of project:	Aug. 2000
End of project:	Dec. 2004

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

A. *Project summary*

A basic aim in organic farming is to optimize the N economy of the cropping system while reducing losses to the environment. For cereal production in particular, N is a key nutrient in achieving acceptable yield levels of sufficient quality e.g. for breadmaking. Cereal crops rely on N mineralized from organic matter in the soil including residues from previously incorporated crops and manures, and on N from manure added directly to the current crop. To improve the overall N use efficiency of the cropping system, the availability of mineral N must be adjusted according to the N demand of the growing crop while surplus mineral N should be conserved in the root zone during breaks between main crops, e.g. by adopting nitrate catch crops or by incorporation of crop residues with a sufficient potential for N immobilization.

One particular challenge to organic farmers is to increase the production of quality cereals for human consumption. Major constraints are the nutrient accessibility and weed controls resulting in too low harvest yields and reduced grain quality. In Denmark, organically grown wheat flour accounts for 8% and wholemeal flour for 17% of the total consumption of these products. Nearly 70% of the consumed organically grown bread wheat is imported. Organically grown wheat tends to have a lower protein content than conventionally produced wheat providing suboptimal baking qualities. The protein content differs among spring and autumn sown wheat varieties. More of the spring wheat samples achieve bread quality (protein-% >10.5) but a large variety-dependent variability is observed. Winter wheat benefits from a long vegetative growth period, its competitiveness towards weeds, and a high yield potential. Spring wheat is interesting due to a higher potential grain quality when grown organically and due to the possibility of avoiding excessive autumn tillage with a subsequent release of non-

exploited mineral N. However, the breadmaking quality of organically grown wheat in relation to N management and crop varieties has not been evaluated thoroughly. New rapid methods for cereal grain quality evaluation, used in combination with conventional quality analyses, allow for more comprehensive studies of bread wheat quality.

The overall objective of the proposed project is to improve the N management and cropping methods in organic plant production in order to enhance the quality and quantity of homegrown bread wheat while improving the crop N-use efficiency and reducing the leaching loss of nitrate from the soil/plant system.

The four work-packages (WP) contribute to the overall objective by focusing on how N accumulated in grazed pastures can efficiently be used for production of bread wheat without excessive nitrate leaching (WP1), on how soil tillage can be implemented for regulating soil N turnover during growth of cereal crops in order the improve the synchrony between soil N mineralization rates and N-uptake (WP2), on how manure placement can enhance cereal crop uptake and increase the competitive ability towards weeds (WP3) and on how the crop variety, N management and baking quality interact (WP4).

The studies draw on a spectrum of cropping systems, soil types and N managements, combining field experimentation and laboratory studies.

WP1: Utilization of N in grazed grass/clover pastures

In cut grassland systems N efficiency is usually high and even at fertilizer application rates of up to 400 kg N ha^{-1} little N is left in the field. Consequently, nitrate leaching following cut grass is often very low. Grazing by e.g. dairy cows has a marked effect on the grassland N cycle and may increase the loss potential dramatically. This is because ruminants excrete 75-95% of their N-intake, most of this being deposited in the field during grazing. Thus a considerable build-up of N takes place in grazed grassland and the extent depends on fertilisation, the feeding strategy of dairy cows, stocking density, grazing periods and the botanical composition of the sward.

The age of the pasture is an important parameter since a new equilibrium in soil N build-up is reached after a number of years, after when the N surplus is lost by leaching. When comparing older and recently established pastures, nitrate leaching losses appear much lower in the newly reseeded fields compared to permanent pasture. There is some uncertainty as to when the N equilibrium is reached. The ploughing of grassland can be followed by a large increase in the mineralisation rate of N, and a well-organized crop rotation is important in order to utilize the N released. The substantial precrop effects observed after ploughing suggest that this is an ideal place in the crop rotation for producing grain cereals with high protein content. However, in some situations it may be necessary to supplement the precrop effect with animal manure to achieve a sufficiently high grain quality. However, this may increase the risk of nitrate leaching.

WP2: Soil tillage strategy and organic matter management for improved N-use efficiency

Synchrony, defined as the temporal matching of N availability and crop N demand, may be improved by adjusting the time, intensity and frequency of soil tillage operations. Although these management parameters are known to influence the mineralization, immobilization and remineralization of N, their potential under field conditions must be better clarified before management strategies that may accomplish a high and predictable crop utilization of N stored in organic matter can be developed and subsequently implemented in organic farming.

The time of ploughing and the intensity of autumn stubble tillage can significantly affect the leaching loss of N during the autumn and winter period, indicating that labile organic N can accumulate in soil and become rapidly mineralized following tillage-induced physical disturbances of soil structure. The effect of tillage on N mineralization during the main growth period has received very little attention.

The amount of labile organic N that can be exposed to rapid mineralization by preplant tillage or tillage within the growth period is considered to depend on the quantity and nature of organic soil amendments in previous years and on the intensity of soil tillage in the preceding autumn and winter period. Soils receiving moderate inputs of organic matter and subjected to intensive autumn tillage are likely to accumulate less labile organic N than soils subject to large organic inputs and minimum tillage. Soil tillage affects N mineralization by changing the particle size and spatial distribution of crop and manure residues in soil and by increasing the intimacy of residue/soil contacts. By breaking soil structural elements, tillage may contribute further to N mineralization by exposing physically protected organic matter to microbial turnover. Depending on its character, the exposed organic matter may also cause N immobilization and thus a temporary reduction in plant available N in soil.

Soil tillage serves a number of purposes in organic cropping systems. Tillage is applied to control weed populations, to incorporate crop residues and manures and to maintain or improve soil mechanical properties, including seedbed preparations. It is essential not to compromise these needs for soil tillage when developing tillage strategies for improved N synchrony in cereal production.

WP3: Crop and weed competition and N uptake as affected by manure placement

Placement of mineral fertilizer N in bands parallel to or below the seed row increases the nutrient uptake, the increase of N in a small grain crop being most pronounced early in the elongation phase. Up to 2/3 of maximum uptake of added N may occur during an almost linear uptake phase of 7 days.

The beneficial effect of banding depends on soil nutrient status. The yield increase appears more significant in poor crop rotations and in low fertility soils. Similarly, a high N immobilisation potential may increase crop N uptake from added fertilizer. Direct injection of animal slurry is most efficient in reducing ammonia volatilization and compared to incorporation of surface applied slurry, banding by direct injection has been found to reduce the microbial immobilization of mineral N added in animal slurry. The reduced immobilization due to banding of mineral N can be reflected in an increased crop N uptake.

Banding of added nutrients may also be effective in managing weeds when combined with other methods of weed control. Banding of animal slurry in organic cropping systems may present a positive effect in relation to weed/crop competition and increased N use efficiency. Dry matter production and recovery of added N in crop and weed during the crop elongation phase can be affected by placement depth of the slurry band. Similarly the effect of distance between the crop row and fertilizer band can be most pronounced. The effect of banding animal slurry is also expected to be expressed over the 2-4 weeks of initial elongation phase.

Recent studies on crop/weed competition show that direct injection is able to reduce weed biomass and subsequent mechanical weed control is in some cases improved by direct injection of animal slurry. Crop/weed competition and weed harrowing can be improved since the crop types and actual weed species have a major influence on the results. Due to earlier emergence, faster initial growth and earlier response to slurry injection, barley may perform better than oat, while experiments with spring wheat with increased nutrient application are seen to both reduce and increase competitive ability of the crop. Due to their rapid growth rate and high nutrient uptake potential, cereals appear to respond more rapidly to resource enrichment than wild plant species. Increased levels of available N generally favour the cereal crop relative to its common weeds. Most weed seeds germinate from the 0-3 cm soil layer, whereas cereal seeds emerge from a sowing depth of 3 to 5 cm. Nutrients placed below and close to crop seeds may present a competitive advantage relative to weeds because of shorter distance to the nutrient and therefore initial root growth may be essential to the outcome of competition for nutrients. However, little is known about differences between initial root growth rates of cereal varieties and weed species and differences between different varieties are not well known.

WP4: Bread wheat quality as affected by crop variety and N management

Breadmaking quality is mainly related to the protein and gluten content of the wheat grain and flour, but gluten structure and functional properties of the gluten are important too. In addition, the gelatinisation properties of starch influence the bread quality. Organically grown wheat tends to have a lower protein content than conventionally produced wheat, resulting in sub-optimal bread-making qualities. Grain samples from organically grown wheat varieties show a large variation in protein content between spring wheat and winter wheat. A significant higher percentage of the spring wheat samples achieves bread quality (protein %>10.5 %), but the variation among varieties can be substantial. Selecting the right varieties for organic farming under restricted N-availability will be a very important task.

Test baking of organically produced flour using conventional baking procedures produce a bread with a lower volume and a less elastic crumb, although the bread volume can be increased by modifying the dough procedure or by addition of natural improving ingredients.

The producers of organic wheat flour claim, however, that organic bread wheat with lower protein and gluten content can result in bread with an acceptable bread volume in test baking. This indicates that there might be a difference in the gluten structure (or in other components in the dough structure) between organic and conventionally grown bread wheat, which implies an improved baking quality. Basic rheological methods have been used for several years for characterisation of rheological properties of gluten in relation to breadmaking performance. Studies on a range of biscuit wheat varieties showed, that rheological methods gave a better evaluation of differences in baking properties between varieties. Rapid test methods have recently become available for qualitative and quantitative evaluations of cereals. These methods are based on near-infrared transmission (NIT) spectrophotometry and optical measurement. Use of these rapid methods for qualitative measurements of grain properties allows more comprehensive analytical studies.

The objectives and expected achievements are presented in Section B and the specific activities in each WP are detailed in Section C1. The Timetable (Table A2) shows the distribution of activities over the project period.

Table A1: Work package list

Work-package No	**Work package title**	**Participants ***	**Budget (1000 DKK)**	**Start**	**End**	**Deliverable No(s):**
WP1	Utilization of N in grazed grass/clover pastures	<u>JE</u>	1446	2001	2004	13, 21, 26, 27
WP2	Soil tillage strategy and organic matter management for improved N use efficiency	<u>IKT</u>, PS, BTC	1864	2000	2004	6, 10, 20, 22, 25
WP3	Crop and weed competition and N uptake as affected by manure placement	<u>JP</u>, KR	1106	2000	2003	3, 7, 11, 12, 17, 18
WP4	Bread wheat quality as affected by crop variety and N management	<u>JRJ</u>, LP	2154	2000	2004	14, 15, 23, 24

* Responsible participants are underlined

Table A2: NIMAB Timetable

Table 4: Time table																																																													
I.4 NIMAB		2000												2001												2002												2003												2004											
Activity	Month	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
	WP1: Utilization of N in grazed grass/clover pastures																																																												
1	Nitrate leaching from older pastures													x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x																														
2	Ploughing grazed pastures with different age																												x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
3	Fertilizer strategy for production of high quality spring wheat after pastures																												x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						
M1	The effect of pasture age on nitrate leaching has been analyzed and results submitted																																																M												
M2	The effincy of precrop effect for production of spring wheat of breadmaking																																																										M		
	quality has been determined and results submitted																																																												
	WP2: Soil tillage strategy and organic matter management for improved																																																												
	N use efficiency																																																												
4	Organic matter levels and tillage frequency															x	x	x	x	x	x	x	x	x																																					
5	Nutrient regime, preplant tillage and crop N uptake pattern								x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x																																					
6	N mineralization rate as affected by intensity of soil disturbance																											x	x	x	x	x	x	x	x	x				x	x	x	x	x	x	x	x	x													
7	Mechanisms that control the retention and mineralization of labile organic N																	x	x	x	x	x						x	x	x	x	x								x	x	x	x	x																	
M3	Strategies for improving N-use effiency in production of wheat of breadmaking																																																	M											
	quality have been investigated and results submitted																																																												
M4	Studies of mechanisms that control the retention and mineralization of labile																																																						M						
	organic N have been carried out and results submitted																																																												
	WP3: Crop and weed competition and N uptake as affected by																																																												
	manure placement																																																												
8	Recovery of 15N in crop and weeds																											x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x														
9	Initial growth of roots								x	x	x	x	x	x																																															
10	Competition between spring wheat and weeds															x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x																									
M5	The effects of placement geometry on 15N-recovery in spring wheat and weeds																																															M													
	have been analyzed and results submitted																																																												
M6	Results on initial root growth and on crop/weed competition have been analyzed and submitted																																			M																									
	WP4: Bread quality as affected by crop variety and N management																																																												
11	Field trial Pajbjergfonden								x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x																												
12	Field trial Research Centre Flakkebjerg								x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x																												
13	NIT and image analysis																					x	x	x	x	x	x							x	x	x	x	x	x							x	x	x	x	x	x									
14	Flour analysis and baking characteristics																					x	x	x	x	x	x							x	x	x	x	x	x							x	x	x	x	x	x									
M7	Quality of organically grown winter wheat varieties analysed and																																							M																					
	results sumbitted																																																												
M8	Competition and synergetic relations between winter bread wheat and green																																													M															
	manure have been studied and results submitted																																																												
M9	Suitable quality standards for organically produced bread wheat have been																																																						M						
	established. Results submitted.																																																												

B. Objectives and expected achievements

The overall aim of the project is to improve the N management and cropping methods in organic plant production in order to enhance the quality and quantity of homegrown bread wheat. This is done by improving the crop N-use efficiency in organic crop production and reducing the leaching loss of nitrate from the soil/plant system. The objectives and expected achievements of the work included in this project are specified below.

WP1: Utilization of N in grazed grass/clover pastures

The objectives are to reduce the loss of nitrate by leaching from grazed grass/clover pasture, to establish the importance of pasture age for N utilization in subsequent crops, and to examine the potential for production of high quality wheat combining precrop effects of grazed grass/clover and dressings of organic manures.

The expected achievements include an improved N utilization on grass intensive dairy farms, a reduced leaching loss of nitrate following termination of grazed grass/clover pastures, and an increased production of high quality wheat for breadmaking.

WP2: Soil tillage strategy and organic matter management for improved N-use efficiency

The objectives are to quantify the potential of soil tillage in regulating soil N turnover during the growth of cereal crops, and to determine the interactions between tillage induced effects on N mineralization and organic matter management. The strategic aim is to improve the synchrony between soil N mineralization rates and N uptake in wheat intended for human consumption.

The expected achievements are to develop tillage strategies that improve the N economy of cereal production on soils with different organic matter management and fertility status.

WP3: Crop and weed competition and N uptakes as affected by manure placement

The objectives are to enhance cereal crop uptake and reduce weed accessibility of N in banded animal slurry dressings by adjusting the slurry placement geometry, and to improve the competitive ability of cereals towards weeds by choice of crop variety and manure application method.

The expected achievements are recommendations for slurry application strategies that will improve exploitation of the N resource in manure and the control of weeds in cereal cropping systems.

WP4: Bread wheat quality as affected by crop variety and N management

Main objectives are to identify crop varieties suitable for organic bread wheat production under Danish growth conditions, to adapt and implement rapid NIT-based methods to test for breadmaking grain quality, to establish suitable quality standards for organically produced bread wheat and to contribute to the clarification of interactions between baking quality, crop variety and N management.

The expected achievements include better test methods and quality standards to be used by farmers, trading and milling industry, and recommendations on choice of crop variety and management for increased production of organically grown wheat for bread purposes.

C. Midterm results and progress

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

WP1: Utilisation of N in grazed grass/clover pastures

The organic grass/clover experiment (GCE, see EXUNIT for further details) at Research Centre Foulum includes four different grassland histories (grazed and cut grass/clover, grazed and cut pure grass). The original grassland histories were established in 1993 and a part was ploughed in 1997 resulting in associated plots of cultivated land and older pastures. Each plot is equipped with three ceramic suction cups for collection of soil water leaching from the root zone. Nitrate leaching is estimated from nitrate concentrations in percolation and the drainage volume. The work in this WP consists of three activities: 1) Nitrate leaching from older pastures, 2) Ploughing grazed pastures with different age, and 3) Fertiliser strategy for production of high quality spring wheat after pastures. Activity 1 has now been completed.

Activity 1: Nitrate leaching from older pastures
Using the suction cup technique nitrate leaching is determined throughout the autumn and winter period by collecting samples of soil water below the root zone weekly or biweekly from grazed (with dairy cows) and cut fields (unfertilised grass/clover and fertilised pure grass). In 2000 one half of each grassland history that was cultivated in 1997 was re-seeded to grass, the other half being re-seeded in 2001. Thus, in the winter 2000-2001 leaching from cultivated land, 1st and 7th year pasture was compared in associated plots, and in the winter 2001-2002 it was possible to compare 1st, 2nd and 8th year pasture allowing for estimates of the effect of increasing N accumulation in grassland on nitrate leaching.

Leaching losses increased from 2000/2001 to 2001/2002, probably as a consequence of increased drainage (from 268 to 430 mm). Leaching losses from grass-clover were low and similar for all sward types ranging from 4 to 21 kg NO_3-N ha^{-1} yr^{-1}. Leaching losses from grazed ryegrass increased dramatically with increasing sward age. Apparently, the build-up of soil N reached equilibrium after 7-8 years of grazing resulting in a larger part of the fertiliser input being lost.

In collaboration with DINOG (I.13) N_2 fixation was determined in grazed fields in 2001 to test if leaching losses were lower in old grass-clover swards as a consequence of decreasing N_2-fixation. N_2-fixation in older swards was decreased and may partly explain lower leaching losses in grass-clover than in fertilised ryegrass. The clover component appears to equalise differences in soil N availability in swards of different age.

Activity 2: Ploughing grazed pastures with different age
In 2002 the pastures of grass-clover and ryegrass were ploughed after 1, 2 and 8 production years. As reference were used associated cut grassland and continuos cereal cropping. The yield in spring wheat was greatly increased by the grassland pre-crop (Fig. 1). The pre-crop effect ranged from about 70 kg N/ha following 1 year of pasture to 100-120 kg N/ha following 8 years of grazed pasture with the highest pre-crop effect following ryegrass. Nitrate leaching following the ploughing of grasslands was determined using the suction cup method in the winter 2002/2003. Due to low drainage this winter (234 mm), nitrate leaching was only moderate, but still differences appeared. Generally, nitrate losses were smallest following ploughing of young grass-clover swards only grazed for 1 year (6 kg NO_3-N/ha) and highest following ploughing of older swards grazed for 2 or 8 years (35 kg NO_3-N/ha). The result followed to some extent what would have been predicted by looking at the differences in pre-crop effect of the swards. It is striking that the EU Drinking Water Directive upper limit of 50 mg nitrate per litre was on average not exceeded in any of the plots where grass-clover was ploughed out but was exceeded in all plots where ryegrass had been grazed for more than 1 year.

Activity 3: Fertilizer strategi for production of high quality spring wheat after pastures
Following the ploughing of the above mentioned grasslands spring wheat were grown with different N-applications in slurry (0, 115 and 230 kg total-N at sowing and a split application with 170 kg total N at sowing and 60 kg at heading). The yield effects of slurry were small, but the protein content was much increased by slurry application (Fig. 1). There was no effect of split application on protein content. Wheat samples have been submitted for determination of bread-making quality.

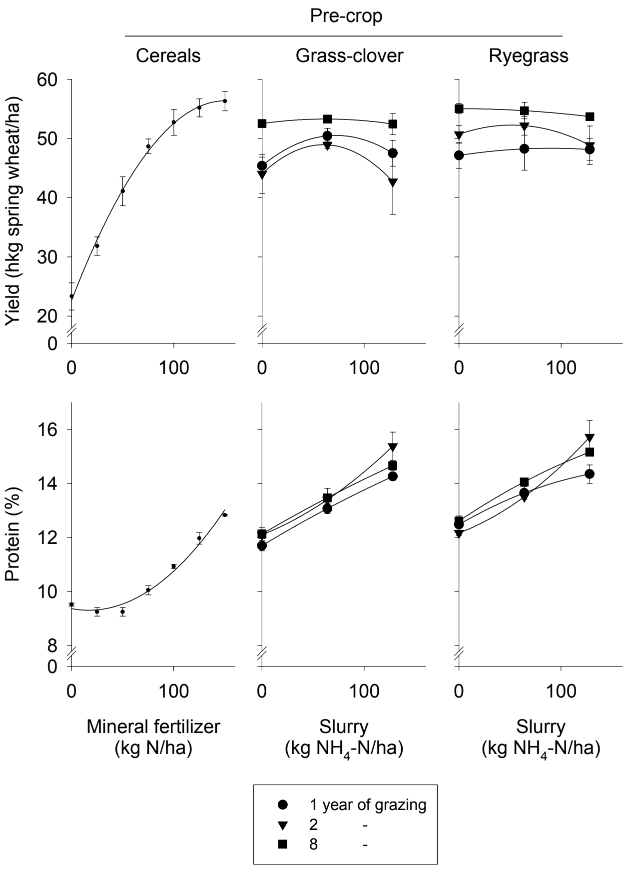


Fig. 1. Yield and protein content of spring wheat following different pre-crops. Error bars: ±SE.

WP2: Soil tillage strategy and organic matter management for improved N use efficiency

Activity 4: Organic matter levels and tillage frequency
This activity was based on The Spring Cereal Rotation of the Systems Research Areas at Foulumgaard. The rotation was established in 1987 and includes different organic matter management strategies: 1 = no additional organic inputs, 2 = nitrate catch crop + animal slurry, 3 = straw + animal slurry, and 4 = nitrate catch crop + straw + animal slurry. Over the years, these strategies have accumulated different levels of soil organic matter.

It was intended to grow spring wheat in the experiment in 2001. However, we were informed by the field experiment manager that the risk of infection of the wheat with the take-all fungus (*Gaeumannomyces graminis*) was very high. It was therefore decided that the experiment should be carried out with spring barley in 2001.

The barley was sown in April at double row spacing (25 cm). Each plot was subdivided into four smaller plots. One of these smaller plots was left undisturbed during the active growth phase. The remaining three plots were exposed to soil disturbance either one (16 May), two (16 May, 30 May) or three (16 May, 30 May, 13 June) times during the growing season. The soil disturbance was carried out with a row cultivator to 8 cm soil depth. Soil samples and plant cuts were taken in the undisturbed and disturbed plots immediately before the soil disturbance and one, two and three weeks after the disturbance.

The soil disturbance raised the inorganic N content with up to 19 kg N ha^{-1} in the first part of the growing season (Fig. 2) but the N uptake in crop samples taken at the same time was not raised correspondingly. Grain yield of barley harvested at maturity was unaffected by the soil disturbance but the total N uptake increased 5 kg N ha^{-1} after one soil disturbance when compared with the other treatments. Grain samples will be analysed as described for Activity 13.

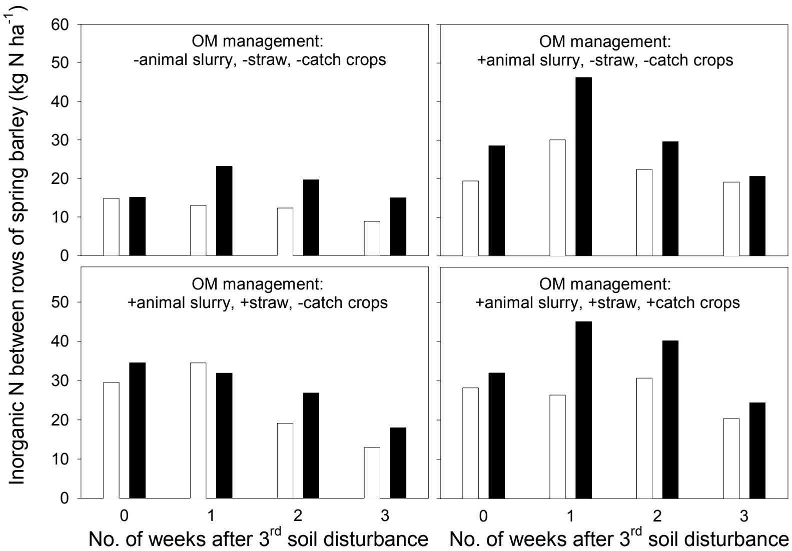


Fig. 2. Inorganic N content in soil between rows of spring barley after three times of soil disturbance (black bars) and in undisturbed soil (white bars).

Activity 5: Nutrient regime, preplant tillage and crop N uptake pattern
The Askov Long-Term Experiments on Animal Manure and Mineral Fertilizers were initiated in 1894. In 1996, one of the four blocks at Lermarken (B4-field) was converted to an organic farming workshop area now comparing equivalent dressings of N, P and K given either in cattle slurry or in farmyard manure. Three nutrient levels are compared with unmanured treatments. Consult EXUNIT (ASK) for further details.

The B4 block at Lermarken grew grass-clover in 2000. In spring 2001 two tillage intensities were applied to each plot before sowing. One half of the plot was ploughed directly. The other half was rotovated intensively before ploughing. All plots were subsequently sown to spring wheat.

The different tillage carried out before sowing the spring wheat had no significant influence on the inorganic N content measured in the soil in the first part of the growing season. Neither was the N uptake in the plant biomass sampled during the same period influenced by the cultivation. When harvested at maturity, the spring wheat grown on plots without rotovation before plowing had a significant higher yield and N uptake than wheat sown in soil rotovated before plowing. Thus the higher intensity associated with the rotovation seemed to lower yield and N uptake rather than raise the yield potential. Grain samples from selected treatments have been submitted for analyses of baking quality (WP4).

Activity 6: N mineralization rate as affected by intensity of soil disturbance
The activity is based on The Spring Cereal Rotation of the Systems Research Areas at Foulumgaard using the same organic matter management strategies as in Activity 4 in this WP. The main plots grown with winter wheat at double row spacing (25 cm) were divided into four subplots each exposed to one of three different tillage intensities or to no soil disturbance. The equipment used for the tillage was a conventional row cultivator, a PTO-driven row rotovator and a brushweeder. All tillage operations were carried out 6 May 2002. Soil samples were taken in the undisturbed and disturbed plots immediately before the soil disturbance and on a weekly basis for four weeks after the disturbance. The soil was sampled within wheat rows and between rows, respectively, and were analysed for inorganic N content. Cuts of the wheat were taken at the same time as soil was sampled. The remaining part of the plot was harvested at maturity.

Immediately before the soil disturbance took place, nitrate content was higher between than within rows (Fig. 3). During the following 28 days, the nitrate content between rows sampled from the undisturbed plots dropped to the same level as in samples taken within rows. In contrast, nitrate contents between rows remained higher in disturbed soil. The highest nitrate content was generally found after the row rotovator (Fig. 3).

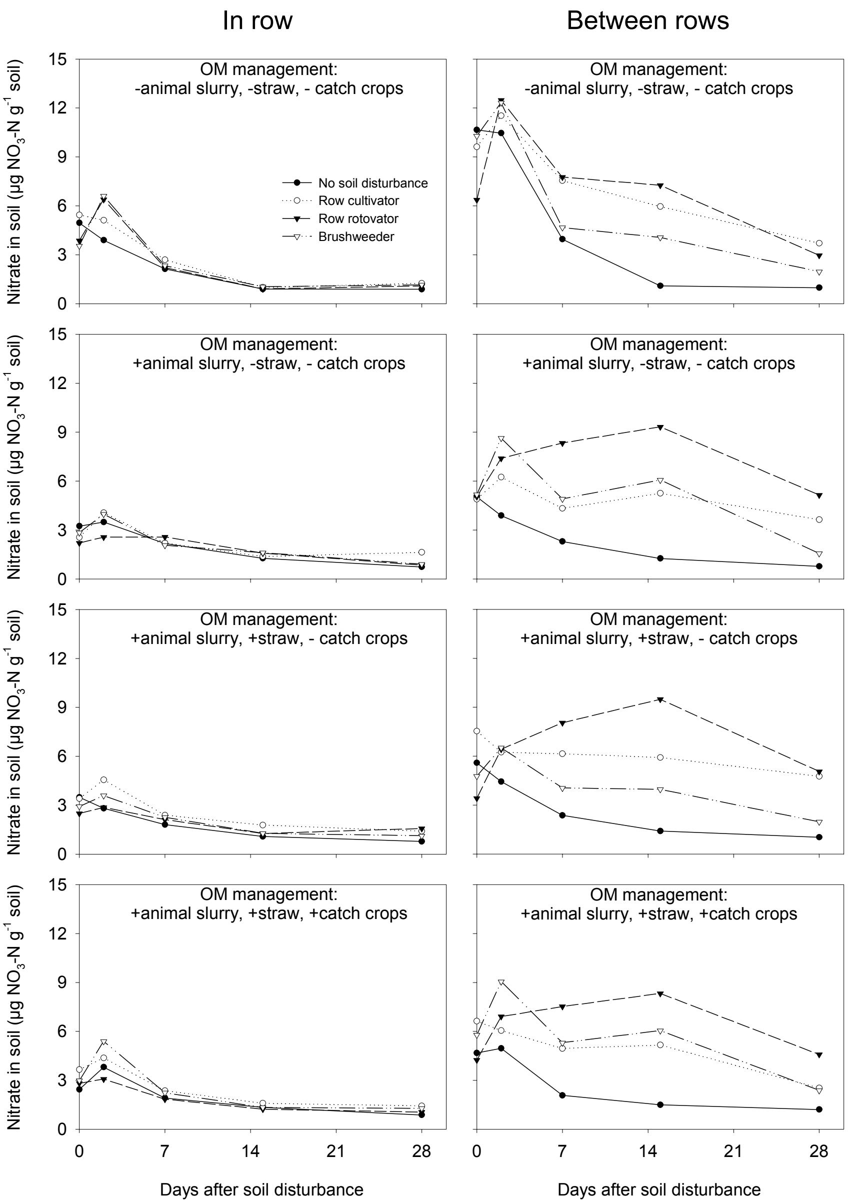


Fig. 3. Nitrate content in crop rows and between crop rows four weeks after soil disturbance.

The wheat biomass harvested at the same times as the soil samples were taken were generally unaffected by the soil disturbance. Thus the wheat did not respond to the higher nitrate content found between rows in the disturbed soil. When harvested at maturity, grain yield was lowest where a row cultivator had been used. No differences were found for grain yield from undisturbed plots and plots with soil disturbance carried out with a row cultivator or brush weeder.

This activity was repeated in another winter wheat field in 2003. Grain samples from 2002 and 2003 will be analysed as described for Activity 13.

Activity 7: Mechanisms that control the retention and mineralization of labile organic N
Gross N transformation rates (mineralization, immobilization, nitrification) were measured in undisturbed and disturbed soil during a period of 10 days after the soil tillage with the PTO-driven row rotovator in Activity 6. In addition N transformation rates after simulated intensive soil tillage (soil sieving) were measured. The measurements were performed in plots with the highest level of organic matter input (nitrate catch crop + straw + animal slurry) and in plots with the smallest level of organic matter input (no additional organic amendments). The N turnover rates in soil were estimated using small additions of highly enriched ^{15}N and the numerical model FLUAZ.

The disturbance introduced with the row rotovator had no consistent effect on the gross N mineralisation proces in soil during the first 10 days (Fig. 4). Unexpectedly gross N mineralization rate was reduced in sieved soil as compared to intact and tilled soil. Gross N immobilisation was slightly lower in the soil with small organic matter inputs compared to high organic matter inputs (Fig. 4). In the soil with high inputs of organic matter, the nitrification rate peaked in intact soil. Soil tillage and sieving had no significant effect on the total amount of mineral N in soil 10 days after the treatment, indicating that the net N mineralization was unaffected by tillage. The gross N turnover can only be estimated with a relatively high variability and the influence of tillage was apparently too low to be detected.

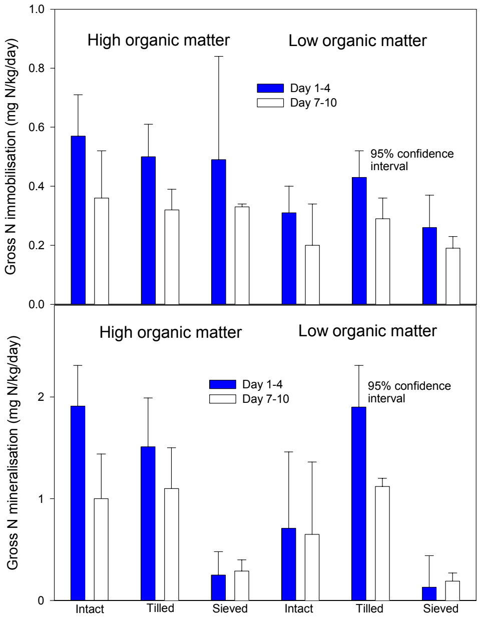


Fig. 4. Gross N mineralisation and immobilisation rates measured in intact, tilled and sieved soil with low and high organic matter inputs.

WP3: Crop and weed competition and N uptake as affected by manure placement

Activity 8: Recovery of ^{15}N in crop and weeds
The results from the experiment in 2002 were treated statistically. Data on recovery of applied ^{15}N was fitted to a sigmoid growth function using the SAS procedure PROC NLMIXED. The plant-available N in slurry applied for the purpose of crop production may be available to weeds as well, and it is clear that the treatments having a positive effect on the crop ^{15}N recovery also depress the weed ^{15}N recovery. Thus, weeds may be a significant competitor for applied nitrogen and within each application method several factors may affect the weed:crop competition for applied nitrogen. Circumstances weakening the crop ability to recover applied N may also cause a change in the weed:crop competition for other growth factors such as light and water, and reduce the possibility to achieve an effective and low cost weed control, mechanical as well as chemical.

Activity 9: Initial growth of roots
Root growth experiments were carried out in November and December 2000. Nine spring wheat varieties, 2 oat varieties, 1 barley variety and 10 weed species were grown under medio April climate in growth cabinets for 14 (one week after emergence), 17, 21 and 24 days in plastic tubes (diameter: 56 mm – height: 330 mm). After 24 days the roots of the cereals were almost at the bottom of the tubes. Germination speed and percentage, root and top length and weight were measured and roots were scanned for further ‘picture analysis’. At the tested conditions the root growth of the cereals was superior to the weeds. Small differences between the wheat varieties were seen compared to other cereals and the weeds. In general barley had a faster root development than spring wheat and the spring wheat was faster than oats and weeds. These results confirm the hypothesis that cereals reach nutrients placed within a certain distance from the germination site before weeds.

Activity 10: Competition between spring wheat and weeds.
Based on the root experiments and availability on the market, the varieties 'Leguan' and 'Dragon' were selected for the field competition experiment. *Lolium multiflorum* was chosen as an artificial competitor. Injection of liquid manure before or after ploughing was compared to surface applied liquid manure before ploughing. A data analysis on plant biomass and densities indicated that application of liquid manure before ploughing is the best application method regarding the crop/weed interactions. Although not significant wheat biomass was highest by injection before ploughing and weed biomass was lowest either by surface application or injection before ploughing. Injection after ploughing seems to influence germination of the crop and to stimulate weed growth. Of the two wheat varieties Dragon tended to be the most competitive, in contrast to results from root growth analysis. One reason could be its longer straw, which provides a higher above ground competition for light. Yield of the variety Dragon was reduced compared to that of Leguan, but the lower yield carries a higher protein content.

WP4: Bread wheat quality as affected by crop variety and N management

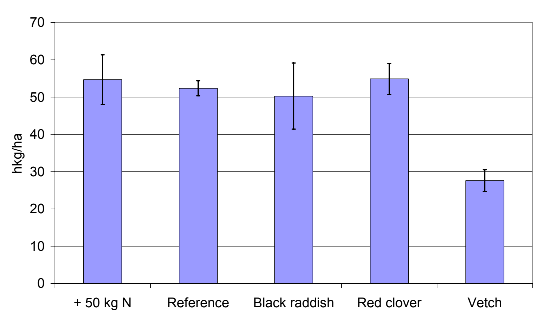
Activity 11: Field Trial Pajbjergfonden
The Danish plant breeding company "Pajbjergfonden" have supplied the project with organic grown winter wheat varieties. In late 1999 Pajbjergfonden initiated a project on "Plant breeding in relation to organic farming" In the project 48 winter wheat varieties are tested in 4 replicated organic grown field trials. Two of these trials were located on commercial organic farms and supplied with pig slurry. Two trials were located at the organic research facillites at Rugballegaard, DIAS-Bygholm. One trial was fertilised with pig-slurry and one with cattle-slurry. The field trials were repeated in 2001 and 2002. The purpose of the project is to identify wheat varieties for organic farming. Approximately 20 of these varieties are also tested in conventional field trials. Grain samples were delivered to laboratory analysis (Activity 13 and 14)

- In 2000, 920 wheat grain samples were collected (26 cultivars), in addition 800 barley samples were collected.
- In 2001, 900 wheat grain samples were collected; in addition, 800 barley samples were collected.
- In 2002, 900 wheat grain samples were collected; in addition, 800 barley samples were collected.

A preliminary interpretation of the analysed data highlighted the problems with the low protein content of organic grown wheat. However, when data were combined with the measurements of the gluten content a few cultivars as Bussard, Hereward, Pentium, and Terra performed better than the average.

Activity 12: Field trial Research Centre Flakkebjerg
In the organic crop rotation area at Research Centre Flakkebjerg (FL1, EXUNIT) a field trial was established in 2001 to examine the interaction between winter wheat and green manure. The field trial was repeated in year 2002/2003. Grain samples were delivered to laboratory analysis at DIAS-PB and DIAS-HC.

The results from the first year indicate a positive effect of winter forms of common vetch (*Vicia sativa* L.) as manure crop. In the growing season of 2002/03 common vetch survived mechanical removal in the spring and occurred as a serious weed influencing the wheat yield (Fig. 5). In the growing season of 2000/01 a significant increase of the grain protein content by 1.3% was obtained with vetch compared to the reference. A similar increase was found in 2003 (Fig. 5). This however, is probably influenced by the low yield.



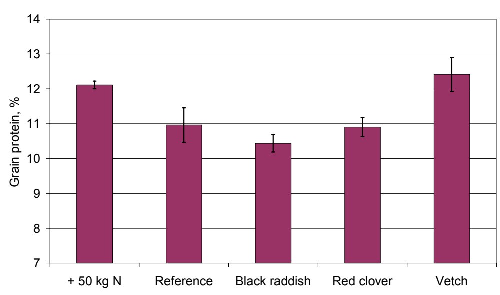


Fig. 5. Grain yield and protein content of the organic grown winter wheat cultivar Asketis in 2003.

Activity 13: NIT and image analysis
The grain analyses focus on qualitative traits of grains. These are measured preliminarily by Near Infrared Transmission (NIT) and image analysis. Development of calibration for NIT scanning allows analysis of wheat grains for content of protein, starch, gluten, water and zeleny number. Image analysis may be used for rapid determination of 1000 kernel weight, kernel shape and colour. Furthermore, specific weight will be measured. Possibly development of new NIT calibrations have be attempted based on the flour analysis. Grain samples from Activity 11 and 12 and from WP1 and WP2 are included.

- In 2000/2001, 2001/2002 and 2002/2003, a total of 2600 wheat grain samples were analysed for content of protein, starch, gluten, water, zeleny, and test weight. In addition, approximately 2300 barley samples were analysed for protein, starch, water and test weight from Activity 11.
- Grain samples were analysed for protein, starch, water, gluten, zeleny, and test weight from Activity 12 (harvest 2000, 2001 and 2003) and from WP1.
- An Access database for results and NIT scans is developed.

The preliminary interpretation of grain measurements by NIT on 30 winter wheat cultivars from 4 organic grown test fields of the year 2000, 2001 and 2002 harvest (Activity 11) have demonstrated that the average protein content of the grain was as low as 9.2% in 2000, 8.5% in 2001 and 10.3% in 2002 (Fig. 6). However, the considerable span in protein content as well as starch content and test measurements of the gluten content have highlighted that specific organic grown grain samples may possess good baking characteristics.

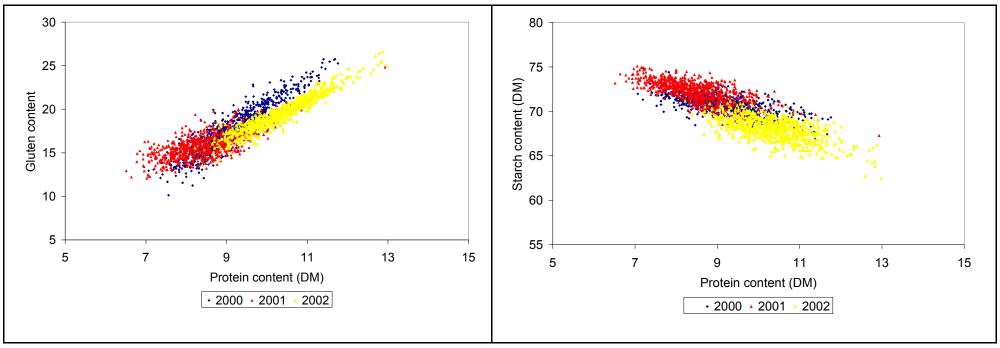


Fig. 6. Grain protein-, starch- and gluten content of 30 winter wheat cultivars grown at 4 organic trials in 2000, 2001 and 2003.

Activity 14: Flour analysis and baking characteristics
From the field trials at Pajbjergfonden (Activity 11), 12 varieties were selected to characterise the baking potential in relation to N management. Grain samples from 2000 and 2001 were collected. Seven different locations were included in the field trial. Samples were milled, and flour analysis included gluten content (ICC-standard) and rheological characterisation of the gluten extracted. The protein content of the grain showed only minor variations among the varieties. The mean value of protein content of flour was 8.3%, which was in the low range for bread wheat application. Therefore, gluten content was also in the low range, especially in the wheat samples from the organic fields. Gluten content from the different fields are shown in Fig. 7. In 2000 the gluten content seemed to be related to the N-input for all the fields. However, in 2001 the gluten content from the organic fields was fairly low, approximately 10-12 %. Comparison of the different varieties showed that Bussard, Hereward, Pentium, and Terra were the varieties, which in organic farming achieved the highest % gluten in relation to the conventional farming. In 2001, it was difficult to evaluate any differences, due to the low level of gluten in the organic fields. Bussard was the only variety, which resulted in % gluten, which corresponds to appropriate baking quality (20-25 % gluten). In the baking tests Bussard also showed the highest bread volume.

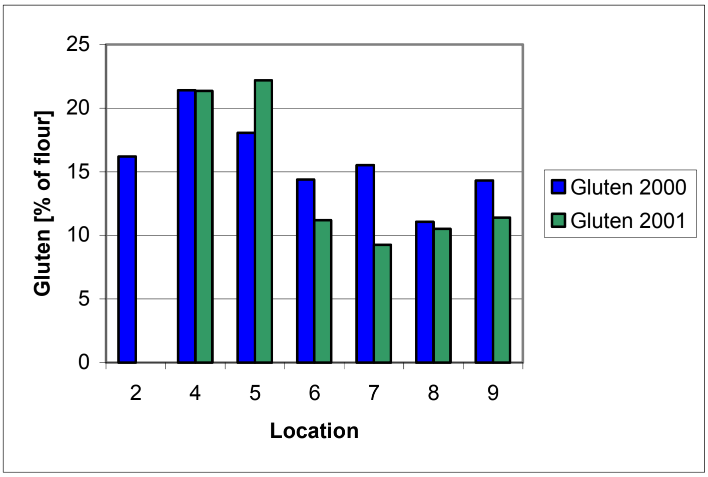


Fig. 7. Mean values of gluten from 11 varieties from 7 fields (Pajbjergfonden).
(2) Conv.-145 kg N; (4) Conv.-170 kg N; (5) Conv.-179 kg N; (6) Org/animal-129 kg N; (7) Org./animal-146 kg N; (8) Org./plant-74 kg N; (9) Org./plant-136 kg N

Spring wheat samples from grazed clovergrass pastures, and fields with mineral fertiliser (WP1) have been milled and the gluten contents were determined (ICC, no. 137). Additionally, gluten properties were determined by rheological characterisation (creep recovery, and oscillation). Generally, protein and gluten from fields with mineral fertiliser were lower compared to the grazed pastures (Fig. 8). In the reference field, the ratio gluten/protein increased for increasing N-levels (1.3 – 2.1), whereas the ratio was almost constant in the grazed pastures (2.0). Protein and gluten from grazed pastures with no fertiliser corresponds to 125 kg N in the reference field, 12.0 % protein and 23.5 % gluten. No effects were observed, when split plot application was done (170+60 kg total N). Apparently, there was a net increase in 'quality yield' (protein and gluten in relation to grain yield), when fertiliser level was increased. The effect of N application on the rheological effects is under investigation. Baking tests on selected samples will be performed.

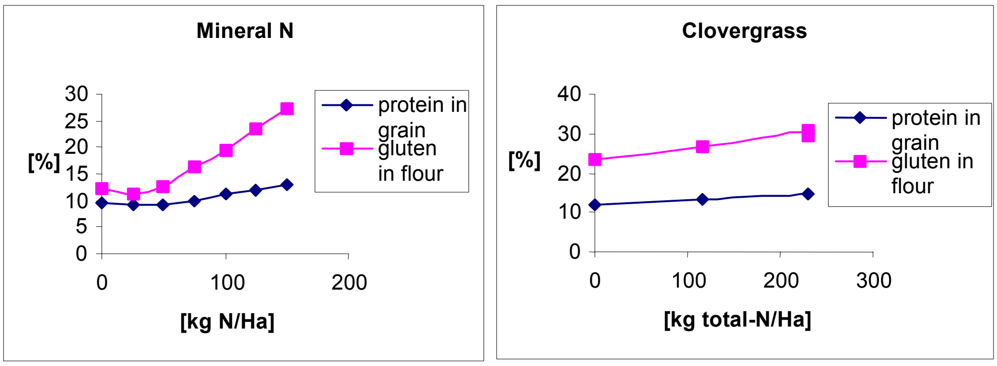
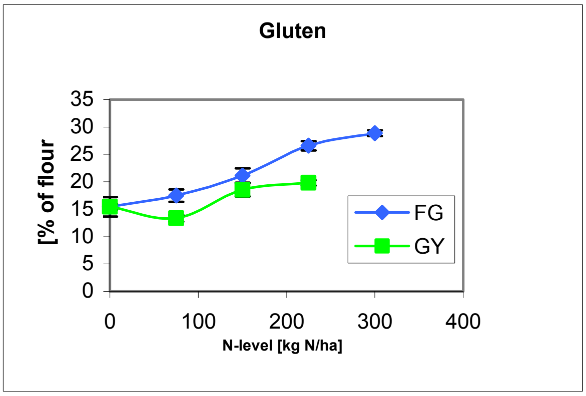
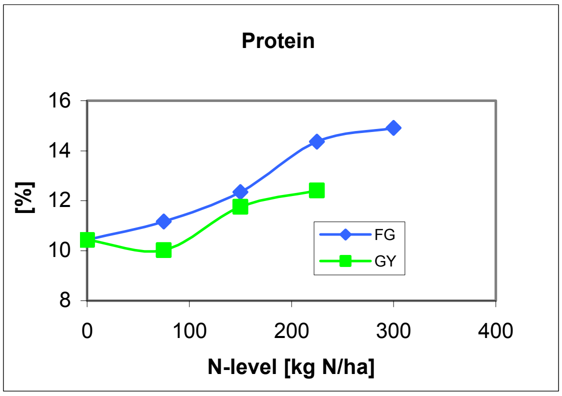


Fig. 8. Protein and gluten from fields with mineral N-fertiliser and grazed pastures (from WP 1).

Spring wheat samples from the field trials at Askov, (2001, WP2) showed a great variability in baking characteristics, due to a wide range in N application. In the Askov field trials cattle slurry or cattle manure are applied in three levels (0, 75, 150, 225 kg N/ha). Results showed that both the type of animal manure and the level of nutrient input significantly affected the protein of the grain and gluten content of the flour (Fig. 9)





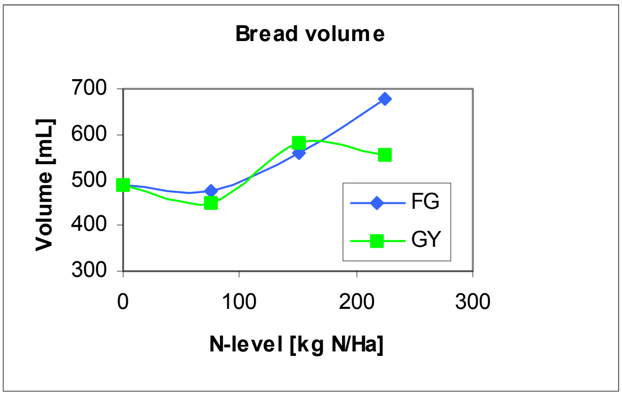


Fig. 9. Gluten, protein and bread volume for the spring wheat Vinjett, Askov 2001. FG: Cattle manure, GY: cattle slurry.

Application of manure (FG) resulted in higher protein and gluten contents, in particular at the high N-input (225 kg N). Baking tests showed only minor differences between FG and GY at N-levels of 75 and 150 kg N, whereas FG increased the volume from 555 to 680 mL Dynamic oscillatory measurements of the gluten are shown in Fig. 10. These results indicate an impact of N-level and at low N-levels also an influence of the type of manure on the elasticity of the gluten. Low levels of N gave an increase in G' and G", which indicate an increase in solid properties of the gluten. This is also reflected in the baking volume, which decreased. At higher N-levels, there were no differences in rheological characteristics between FG and GY. The difference in bread volume at high N-level (225 kg N) could therefore only be related to the difference in gluten content.

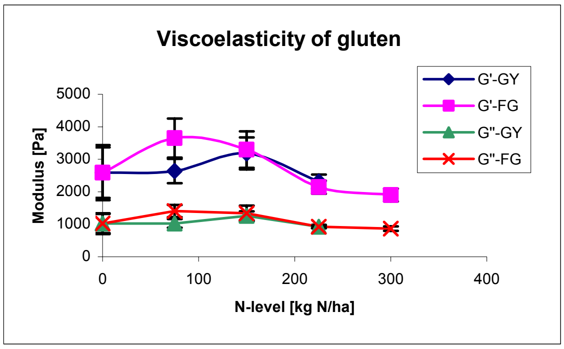


Fig. 10. Elastic modulus, G', and loss modulus, G" of gluten. (Vinjett, Askov 2001).

C.2 Fulfilment of deliverables and milestones

(To be completed for each work package)

WP0 Common part of the NIMAB project	Time schedule according to application	Deviations, if any*
Deliverables		
D1 Timetable, version 2	Nov2000	
D2 1st status report	Nov2000	
D4 Timetable, version 3	Nov2001	
D5 2nd status report	Oct2001	
D8 Timetable, version 4	Nov2002	
D9 3rd status report	Nov2002	
D16 Timetable, version 5	Nov2003	
D19 4th status report	Nov2003	
D28 Final report	Nov2004	

** Deviations are to be further discussed at D*

WP1 Utilization of N in grazed grass/clover pastures	Time schedule according to application	Deviations, if any*
Deliverables		
D13 Grain samples for breadmaking quality analysis	Dec2002	
D21 Paper on nitrate leaching from pastures submitted	Dec2003	
D26 Paper on N-utilization when ploughing pastures submitted	Oct2004	
D27 paper on good management practices when ploughing pastures submitted	Oct2004	
Milestones		
M1 The effect of pasture age on nitrate leaching has been analyzed and results submitted	Dec2003	
M2 The efficiency of precrop effect for production of spring wheat of breadmaking quality has been determined and results submitted	Oct2004	

WP2 Soil tillage strategy and organic matter management for improved N-use efficiency	Time schedule according to application	Deviations, if any*
Deliverables		
D6 Grain samples for breadmaking quality analysis	Oct2001	
D10 Grain samples for breadmaking quality analysis	Nov2002	
D20 Grain samples for breadmaking quality analysis	Nov2003	
D22 Paper on synchronizing N utilization by time and intensity of tillage submitted	Jan2004	
D25 Paper on N turnover as affected by soil disturbance submitted	Jul2004	
Milestones		
M3 Strategies for improving N-use efficiency in production of wheat of breadmaking quality have been investigated and results submitted	Jan2004	
M4 Studies of mechanisms that control the retention and mineralization of labile organic N have been carried out and results submitted	Jun2004	

WP3 Crop and weed competition and N uptake as affected by manure placement	Time schedule according to application	Deviations, if any*
Deliverables		
D3 Grain samples for breadmaking quality analysis	Oct2001	X
D7 Grain samples for breadmaking quality analysis	Oct2002	

D11 Report on initial root growth and competitive ability of cultivars as influenced by nutrient source and application method submitted	Dec2002	
D12 Leaflet on weed control in high quality spring wheat	Dec2002	
D17 Paper on 15N uptake in crop and weeds as affected by placement submitted	Nov2003	
D18 Leaflet on N uptake in crop and weeds as affected by placement submitted	Nov2003	
Milestones		
M5 The effects of placement geometry of 15N-recovery in spring wheat and weeds have been analyzed and results submitted	Nov2003	
M6 Results on initial root growth and on crop/weed competition have been analyzed and submitted	Nov2002	X

WP4 Bread wheat quality as affected by crop variety and N management	Time schedule according to application	Deviations, if any*
Deliverables		
D14 Paper on recommendations on choice of variety of organically grown winter wheat for breadmaking	Mar2003	X
D15 Paper on competition and synergetic relations between winter bread wheat and green manure	Sep2003	X
D23 Paper on suitable quality standards for organically produced bread wheat	Jun2004	
D24 paper on development of rapid non-destructive spectral quality analysis	Jun2004	
Milestones		
M7 Quality of organically grown winter wheat varieties analyzed and results submitted	Mar2003	
M8 Competition and synergetic relations between winter bread wheat have been studied and results submitted	Sep2003	
M9 Conclusions on studies of gluten structure and breadmaking properties. Results submitted	Jun2004	

D. Description of deviations and subsequent adjustments of plans

In Activity 10 (WP3), the field experiment on competition between spring wheat and weeds was severely affected by heavy rain in 2001. The first block was harvested the 1st of September but an unusually long period of rain and wet conditions prevented further harvesting until the 26th of September. Fortunately the yield and quality did not change during this period, but the deliverables of grain samples (D3) for breadmaking quality analysis might be analysed further before the final conclusions. In 2002 the harvest was conducted without any problems the 20th of August.

Deliverables D14 “Paper on recommendations on choice of variety of organically grown winter wheat for breadmaking” is postponed to march 2004. The planned timetable is one year to early, due to the fact, that grain and flour analysis from the year 2002 and 2003 harvest were planed to finish in the autumn of 2003.

In Activity 11 (WP4) Additional 2300 barley samples were analysed by NIT for protein, starch, water and test weight from Activity 11. This activity was not planned at project start. A PhD student at DIAS-PBI is going to study these data in her PhD project. Image analysis of wheat samples from the 2000, 2001 and 2002 harvest is only performed on a selection of the entire wheat sample collection. Grain analyses have focused on NIT analysis.

In Activity 12 (WP4) the field experiment to examine the competition and synergetic relations between winter bread wheat and green manure could not be sown in autumn 2001 due to extremely wet and poor soil conditions for the establishment of the green manure crops. The field trial was therefore established in 2002 and harvested in 2003. D15 is therefore postponed to June 2004.

Department of Plant Biology, DIAS-Flakkebjerg have invested in a new Flour Module and a Colour Module for the Infrarec® 1241 NIT grain analyser (The funding for this is not DARCOF II). The partners of WP4 are examine the performance of measurements of ash and protein content as well as gluten content on flour samples from Activity 14. If successful, an increased number of flour samples could be analysed for these parameters at low cost. This represents a new activity.

E. Project publications and other products

1. Articles in international, scientific journals with review procedures

Christensen, B.T. (2001) Physical fractionation of soil and structural and functional complexity in organic matter turnover. European Journal of Soil Science 52, 345-353. **

Christensen, B.T. (2003) Tightening the nitrogen cycle. In P. Schjønning et al. (eds.) Managing Soil Quality – Challenges in Modern Agriculture. CABI Publishing, Wallingford, UK, pp 47-67. **

Eriksen J. & Jensen L.S. (2001) Soil respiration, nitrogen mineralisation and uptake in barley following cultivation of grazed grasslands. Biology and Fertility of Soils 33: 139-145.**

Eriksen J. & Vinther F.P. (2002) Nitrate leaching in grazed grasslands of different composition and age. Grassland Science in Europe 7: 682-683.

Eriksen J. (2001) Nitrate leaching and growth of cereal crops following cultivation of contrasting temporary grasslands. Journal of Agricultural Science 136: 271-281.**

Guggenberger, G., Christensen, B.T. & Rubæk, G.H. (2000) Isolation and characterization of labile organic phosphorus pools in soils from the Askov long-term field experiments. Journal of Plant Nutrition and Soil Science 163, 151-155. **

Hansen, P.M. Jørgensen, J.R. Thomsen, A. (2002) Partiel least square regression predicting grain yield and protein content in spring barley and winter wheat using repeated canopy reflectance measurements. Journal of Agricultural Science, Cambridge, 139, 307-318.**

Nørbæk, R., Aaboer, D.B.F., Bleeg, I.S., Christensen, B.T., Kondo, T. & Brandt, K (2003) Flavone C-glycoside, phenolic acid and nitrogen content in leaves of barley subject to organic fertilization treatments. Journal of Agricultural and Food Chemistry 51, 809-813. *

Petersen, J. (2003) Weed:spring barley competition for applied nitrogen in pig slurry. Weed Research 43, 33-39. **

Rasmussen, K. (2002) Influence of liquid manure application method on weed control in spring cereals. Weed Research 42, 287-298. **

Schjønning, P., Thomsen, I. K., Moldrup, P. and Christensen, B. T. (2003). Linking soil microbial activity to water- and air-phase contents and diffusivities. Soil Science Society of America Journal 67, 156-165. **

Thomsen, I.K. and Schjønning, P., Olesen, J.E. and Christensen, B. T. (2003). C and N turnover in structurally intact soils of different texture. Soil Biology and Biochemistry 35, 765-774. **

Thomsen, I.K. and Schjønning, P. and Christensen, B. T. (2003). Mineralization of ^{15}N-labelled sheep manure in soils of different texture and water contents. Biology and Fertility of Soils 37, 295-301. **

2. Papers presented at congresses, symposiums, etc.

Christensen, B.T. (2000) Hvad forstås ved begrebet jordens frugtbarhed. Indlæg ved Det Kgl. Danske Landhusholdningsselskabs Efterårskonference, Forskningscenter Foulum, 8-11-2000. Tidsskrift for Landøkonomi 187, 276-279. **

Eriksen J. (2001) Eftervirkning af kløvergræs. I “Bilag til Efterårskonference 2001” s 64. 2. oktober 2001, Hotel Nyborg Strand.*

Jørgensen, J.R. (2000). Er der lighedstegn mellem proteinprocent og kvalitet af hvede til human konsum? Efterårskonference 2000, 3. oktober 2000, Hotel Nyborg Strand. Bilag til Efterårskonference 2000, 36. **

Pedersen, L. (2002). Quality assessment of organic wheat. LMC congress, January 2002, DTU, Lyngby. (Abstract).

Pedersen, L. and Thomsen, I.K. (2003). Properties of gluten from organic wheat measured by oscillation measurements. Annual Transactions of The Nordic Rheology Society, vol. 11., 153.

Petersen, J. (2002). Konkurrence mellem afgrøde og ukrudt om tilført husdyrgødningskvæl-stof. 19. Danske Planteværnskonference 2002, 5. marts på Hotel Nyborg Strand. Danmarks JordbrugsForskning, rapport nr. 64 Markbrug, 119-127. **

Vinther F.P. & Eriksen J. (2001). Measurement of CO_2 evolution in situ. Proceedings from COST 627 Carbon storage in European grasslands, Trinity College Dublin p. 18.**

3. Reports, articles in agricultural journals, etc.

Emanuelson, J., Wollenweber, B., Jørgensen, J.R., Andersen, S.B.F. & Jensen, C.R. (2003). Wheat grain composition and implications for bread quality. DIAS report 92, 40 pp. *

Eriksen (2003) Afgræsningsmarkers eftervirkning. Økologisk Jordbrug 283: 6.

Eriksen J. & Mogensen J. (2001) Forfrugtsværdi og N-udvaskning efter ompløjning af flerårige græs-marker med forskellige forhistorier. DJF rapport nr. 46 Markbrug. 40 pp.**

Eriksen J. & Mogensen J. (2001) Ompløjning af afgræsningsmarker. Forfrugstværdi og N-udvaskning. Grøn Viden Markbrug nr. 237.**

Eriksen J. & Sørensen P. (2002) Eftervirkning af afgræsningsmarker og husdyrgødning. I "Kvælstofba-lancer på landbrugsbedriften – status og perspektiv". Intern DJF rapport nr. 157: 25-30.*

Eriksen J. (2001) Ompløjning af græsmarker kan give stor udvaskning. Økologisk Jordbrug 242: 6.*

Hansen, E.M.; Thorup-Kristensen, K. & Jørgensen, J.R. (2003). Grønne marker. I Forberedelse af Vandmiljøplan III. Rapport fra Kvælstofgruppen (F10). Forbedret kvælstofudnyttelse i marken og effekt på kvælstoftab 198-203. **

Jørgensen, J.R. (2003) Tidlig såning af vintersæd. I Forberedelse af Vandmiljøplan III. Rapport fra Kvælstofgruppen (F10). Forbedret kvælstofudnyttelse i marken og effekt på kvælstoftab 76-81. **

Jørgensen, J.R. (2001). Handels- og forbrugsmønstre i Danmark. DJF-rapport nr. 53, Produktion af kva-litetshvede i Danmark (ed. Waagepetersen, J., Petersen, J.B., Knudsen, L., Deneken, G. & Jørgensen, J.R), 22-24. **

Jørgensen, J.R. (2001). Kvalitet af hvede til produktion af brød og andre produkter. DJF-rapport nr. 53, Produktion af kvalitetshvede i Danmark, (ed. Waagepetersen, J., Petersen, J.B., Knudsen, L., Deneken, G. & Jørgensen, J.R), 25-32. **

Jørgensen, J.R., (2001). Kvalitet af sidstindlejret protein i kernen ved ekstra kvælstofgødskning. DJF-rapport nr. 53, Produktion af kvalitetshvede i Danmark, (ed. Waagepetersen, J., Petersen, J.B., Knudsen, L., Deneken, G. & Jørgensen, J.R), 67-70. **

Petersen, J. (2002) Ukrudt stjæler gødningskvælstof. Landsbladet nr. 47, 22. november 2002, 2. sek-tion, Landsbladet Agro, side 32 (bagside).

Petersen, J. (2003) Konkurrence om gødningskvælstof. Økologisk Jordbrug nr. 280, 10. januar 2003, p. 4.

Thomsen, I. K. (2003). Kun lille N-effekt af jordløsning i vårbyg. Landbrugsmagasinet Landsbladet, 31. januar p. 32.

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

Jørgensen, J.R. (2001). Dyrkning af nøgen havre og højlysin byg. Foredrag givet ved "Proteinafgrøder i økologisk jordbrug - dyrkning og fodring" En temadag på snoghøj IT-højskole den 28.11.2001. Arrangør Brancheforeningen for Økologisk Planteavl. *

Jørgensen, J.R. (2001). Proteinafgrøder i økologisk jordbrug - Nøgen havre og højlysin byg Indlæg på møde vedr. Demonstrationsprojekt om Proteinafgrøder i økologisk jordbrug, Økologiens Hus, 5. april 2001. *

Jørgensen, J.R. (2002). Agronomy and grain quality. Øresund Food Network Seminar: Innovative whole grain cereal products with health profile. 2 - 3 December 2002, Scandic Star Hotel, Lund, Sweden. *

Jørgensen, J.R., 2002. Variation i indholdsstoffer i korn. Workshop om 'Frø- og kornkvalitet. Forsk-ningscenter Flakkebjerg, 18. december, 2002. *

Jørgensen, J.R., 2003. Kvalitetsmål i korndyrkningen. Forsøgsstrategimøde 2003. SCC, Scandinavian Congres Centre, Århus. 16. januar 2003. *

Jørgensen, J.R., 2003. Kvalitetsmål i korndyrkningen. Studiebesøg: Bestyrelse for Landbrugets korn-forædlingsfond, Forskningscenter Flakkebjerg, 31. juli, 2003. *

Pedersen, L. (2003). Dyrkningsforholdenes indflydelse på bagekvaliteten. Indlæg på møde vedr. de-monstrationsprojekter i Økologisk Landsforening, Økologiens Hus, 13. marts 2003.

Pedersen, L. (2003). Kvalitet af hvede til brød - Kvalitetsmål og indflydelse af dyrkningsbetingelser. Foredrag ved kursus 'Økologiske feltdage', Landscentret|Planteavl, Forskningscenter Årslev, 20. juni 2003.

Petersen, J. (2002) Afgrøde og ukrudt konkurrerer om kvælstof (Crop and weed compete for nitrogen). Poster presentation at open day, Foulumgård 13. june 2002.
Thomsen, I.K. (2002). Kan kvælstofmineraliseringen styres ved jordløsning? Åbent Hus, Forskningscenter Foulum, 13. juni 2002.
Thomsen, I.K. (2003). Kvælstofmineralisering efter jordløsning i vinterhvede. Åbent Hus, Forskningscenter Foulum, 12. juni 2003.

F. Scientific education

M.Sc. student Jens Prior Hansen (2003-2004): Residual effect of ploughing out grasslands as a function of grassland age, management and fertilization.

G. National and international cooperation

- All WPs have research activities associated with the DARCOF project IV.1 EXUNIT: Experimental units for research in organic farming systems. The collaboration has involved transfer of basic soil and crop data from EXUNIT to NIMAB and the experimental units have provided the general framework for NIMAB activities.
- WP1 and WP2 collaborate with DARCOF project I.3 BIOMOD: Interactions between nitrogen dynamics, crop production and biodiversity in organic crop rotations analysed by dynamic simulation models. The collaboration includes data delivery, interactions regarding N modelling and basic designs of C model modules. Contacts to Lars Stoumann Jensen, Jørgen Berntsen and Bjørn Molt Petersen.
- WP2 collaborates with DARCOF project I.7 ROMAPAC: Soil quality in organic farming: Effects of crop rotations, animal manure and soil compaction. The collaboration includes common field experiments (se Activity 4, 6 and 7) and data sharing regarding crop yields. Contact to Per Schjønning.
- WP1 collaborates with DARCOF project I.13 DINOG: Dinitrogen fixation and nitrous oxide losses in organic grass-clover pastures: An integrated experimental approach. The collaboration includes measurements of N_2 fixation and N_2O losses from the field treatments included in WP1. Contact to Finn P. Vinther and Søren O. Petersen.
- The Danish plant breeding company “Pajbjergfonden” supplies the project with organic grown winter wheat varieties.
- Baking characteristics tests are conducted in collaboration with the milling company “Drabæks Mølle”.
- Collaboration with Professor Lars Munck, Food technology (Spectroscopy and Chemometrics), Dairy and Food Science, Royal Veterinary and Agricultural University, on use of spectroscopy and chemometrics in quality determination in cereals.
- Collaboration with Department of Organic Farming at Christian-Albrechts-University of Kiel will be used in the interpretation of the nitrate leaching from pastures and quality wheat production (Prof. Dr. F. Taube and Dr. R. Loges).
- Root growth patterns (winRHIZO) are analyzed in collaboration with “Pajbjergfonden” and Kai Lønne Nielsen.

Critical reflection on the project

One characteristic feature of the NIMAB project is the aggregation of widely different scientific competences associated with bread wheat production. Traditionally, the various phases of wheat production have been studied in different, isolated projects. The collective expertise of the NIMAB research group covers widely, including disciplines related to soil science (organic matter and N turnover in soil), plant biology (plant breeding and cultivar performance, plant development and phenology), field crop management (tillage, weed control, animal grazing, fertilization), and food science (grain quality and baking characteristics). This broad scientific competence allows the NIMAB project to establish an intimate link between soil and crop management and the quality characteristics of the end products. In that sense, the NIMAB project represents a unique interdisciplinary effort. We are confident that this will result in new and transgressing research output of great relevance to organic farming. The transdisciplinary nature of NIMAB has accomplished an additional and important goal by enriching and widening the competence of the participating researchers.

Several of the key activities in the NIMAB project rely on access to longer-term field experiments with well-known history, carefully controlled management, and financial backing from external sources. The availability of these experiments presents a unique resource for research projects addressing aspects of soil fertility, including the turnover of organic matter and associated plant nutrients including N. It is of crucial importance, not only to NIMAB, that the institutes responsible for the maintenance of long-term experiments continue to allocate sufficient resources for this purpose. Experimental plans for these experiments have by the very nature of the experiments to be kept unchanged for longer periods and project activities have occasionally to be modified in order not to jeopardize the integrity of the long-term experiments. However, the diversity of treatments most often allows short-term projects to exploit this resource base, as illustrated by NIMAB activities.

The NIMAB project has been successful in establishing extensive collaboration with other DARCOF projects and with private companies (see Section G). This collaboration is considered important for several reasons. The collaboration promotes the dispersal of NIMAB results to other relevant DARCOF activities and *vice versa*, and has allowed additional measurements of parameters that supplement the results generated in NIMAB. The involvement with I.7 ROMAPAC has resulted in data sharing and the establishment of a common field plan, an arrangement promoting high resource use efficiency. The collaboration with the plant breeding company and the milling industry has not only allowed for supplementary activities but has also ensured rapid dispersal of research outcome to an important fraction of end users. The commitment of the private sector in providing grain samples and tests of wheat flour baking characteristics is one illustration of the relevance of NIMAB to organic farming.

8. Budget

A. Account for any change in budgets

B. Budget for the whole project (1.000 DKK)

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

Year:	Consump-tion before 2003	Expected consumption 2003	2004	2005	2006	Total
Man-months						
Scientific personnel	41.5	23.25	15.75			80.5
Technical personnel	39	14	5.5			58.5

Year:	Consump-tion before 2003	Expected consumption 2003	2004	2005	2006	Total
Salaries						
Scientific personnel	1447	813	586			2846
Technical personnel	916	356	136			1408
Other operational costs	863	310	49			1222
Equipment						
Others (please specify)						
Direct costs	3226	1479	771			5476
Indirect costs (20% of direct costs)	644	295	154			1094
Total	3870	1774	926			6570

Comments:

9. Signatures and stamps

Name	Institute	Date	Signature
Head of project			

Appendix I. Detailed budget

A. Budget for each participating institute (1.000 DKr)

Name of Institute: Danish Institute of Agricultural Sciences

Year:	Consump-tion before 2003	Expected consumption 2003	2004	2005	2006	Total
Man-months						
Scientific personnel	41.5	23.25	15.75			80.5
Technical personnel	39	14	5.5			58.5

Year:	Consump-tion before 2003	Expected consumption 2003	2004	2005	2006	Total
Salaries						
Scientific personnel	1447	813	586			2846
Technical personnel	916	356	136			1408
Other operational costs	863	310	49			1222
Equipment						
Others (please specify)						
Direct costs	3226	1479	771			5476
Indirect costs (20% of direct costs)	644	295	154			1094
Total	3870	1774	926			6570

Comments:

B. Budget for each participating department (1.000 DKK)

Name of Institute: Danish Institute of Agricultural Sciences, Dept. Agroecology (DAE)

Year:	Consump-tion before 2003	Expected consumption 2003	2004	2005	2006	Total
Man-months						
Scientific personnel	24	19.25	10.75			54
Technical personnel	24	8	4			26

Year:	Consump-tion before 2003	Expected consumption 2003	2004	2005	2006	Total
Salaries						
Scientific personnel	822	673	412			1907
Technical personnel	325	202	99			626
Other operational costs	453	195	39			687
Equipment						
Others (please specify)						
Direct costs	1600	1070	550			3220
Indirect costs (20% of direct costs)	319	213	111			643
Total	1919	1283	661			3863

Comments: 0.75 scientific man-month has been moved from 2003 to 2004 (WP1)

Name of Institute and department: Danish Institute of Agricultural Sciences, Dept. Plant Biology (PB)

Year:	Consump-tion before 2003	Expected consumption 2003	2004	2005	2006	Total
Man-months						
Scientific personnel	6	2	3			11
Technical personnel	9	2.5	1			12.5

Year:	Consump-tion before 2003	Expected consumption 2003	2004	2005	2006	Total
Salaries						
Scientific personnel	211	70	105			386
Technical personnel	225	62	25			312
Other operational costs	147	53				200
Equipment						
Others (please specify)						
Direct costs	583	185	130			898
Indirect costs (20% of direct costs)	116	37	26			179
Total	699	222	156			1077

Comments: 2 scientific and 1 technical man-months have been moved from 2003 to 2004

Name of Institute and department: Danish Institute of Agricultural Sciences, Dept. Horticulture (HC)

Year:	Consump-tion before 2003	Expected consumption 2003	2004	2005	2006	Total
Man-months						
Scientific personnel	5.5	2	2			9.5
Technical personnel	9	3.5	0.5			13

Year:	Consump-tion before 2003	Expected consumption 2003	2004	2005	2006	Total
Salaries						
Scientific personnel	204	70	69			343
Technical personnel	225	92	12			329
Other operational costs	153	62	10			225
Equipment						
Others (please specify)						
Direct costs	582	224	91			897
Indirect costs (20% of direct costs)	117	45	18			180
Total	699	269	109			1077

Comments: 1 scientific man-month has been moved from 2003 to 2004

Name of Institute and department: Danish Institute of Agricultural Sciences, Dept. Crop Protection (CP)

Year:	Consump-tion before 2003	Expected consumption 2003	2004	2005	2006	Total
Man-months						
Scientific personnel	6					6
Technical personnel	7					7

Year:	Consump-tion before 2003	Expected consumption 2003	2004	2005	2006	Total
Salaries						
Scientific personnel	210					210
Technical personnel	141					141
Other operational costs	110					110
Equipment						
Others (please specify)						
Direct costs	461					461
Indirect costs (20% of direct costs)	92					92
Total	553					553

Comments:

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

Name of Institute:

Year:	Consump-tion before 2003	Expected consumption 2003	2004	2005	2006	Total
Man-months Scientific personnel Technical personnel						

Year:	Consump-tion before 2003	Expected consumption 2003	2004	2005	2006	Total
Salaries Scientific personnel Technical personnel						
Other operational costs						
Equipment						
Others (please specify)						
Direct costs						
Indirect costs (20% of direct costs)						
Total						

Comments: