



**Midterm Status Report 2003 and
Application for Continuation in 2004**

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

1. Research program

Research in organic farming 2000-2005 (DARCOF II)

2. Project title and number

Nitrate leaching from dairy farming. Effect of grassland composition and frequency. (I.15)

3. Head of project

Jørgen Eriksen, Senior Scientist,
Department of Crop Physiology and Soil Science,
Danish Institute of Agricultural Sciences. P.O. Box 50, 8830 Tjele
Ph.: 89 99 18 70, Fax: 89 99 17 19
E-mail: Jorgen.Eriksen@agrsci.dk

4. Participating institutes

Danish Institute of Agricultural Sciences (DJF), P.O. Box 50, 8830 Tjele.
Ph.: 89 99 19 00
Royal Veterinary and Agricultural University (RVAU), Højbakkegaard Allé 30,
2630 Taastrup. Ph.: 35283560

5. Other project staff

Senior Scientist Elly Møller Hansen (EMH), Dept. of Crop Physiology and Soil Science,

DIAS Tlf. 89991760, Fax 89991719, e-mail: Elly.M.Hansen@agrsci.dk
Senior Scientist Ib S. Kristensen (ISK), Dept. of Agricultural Systems, DIAS
Tlf. 89991205, Fax 89991200, e-mail: IbS.Kristensen@agrsci.dk
Senior Scientist Jørgen E. Olesen (JEO), Dept. of Crop Physiology and Soil Science, DIAS
Tlf. 89991659, Fax 89991619, e-mail: JorgenE.Olesen@agrsci.dk
Scientist Margrethe Askegaard (MA), Dept. of Crop Physiology and Soil Science, DIAS
Tlf. 89991702, Fax 89991719, e-mail: Margrethe.Askegaard@agrsci.dk
Associate Prof. Henning Høgh-Jensen (HHJ), Department of Agricultural Sciences, RVAU
Tlf. 35283391, Fax 35282175, e-mail: hhj@kvl.dk
Ph.D. student (NN), Department of Agricultural Sciences, RVAU

6. Project period (month, year)

Start of project: 01-2003

End of project: 12-2006

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

A. Project summary

In nitrate vulnerable zones with agricultural production organic dairy farming may present an opportunity to reduce nitrate leaching if grassland N is efficiently utilised. The objective of the project is to determine the importance of the grassland composition and frequency in the crop rotation for residual effects on yield and nitrate leaching during grazing and following ploughing in order to 1) increase the total N use efficiency of the crop rotation and reduce N leaching losses from dairy crop rotations, 2) suggest specific changes to management and rotation, that may be carried out in e.g. nitrate vulnerable zones within the short term, and 3) establish a scientific sound basis for giving advise on these matters in both organic and conventional farming. The work includes determination of precrop effect and nitrate leaching following ploughing of grassland as affected by grassland frequency in the crop rotation and with comparison between grass-clover and fertilised pure ryegrass.

The results from the experiment are relevant for planing organic crop rotations, especially in nitrate vulnerable zones. The relevance of this type of information increases with the development towards increasing farm size. On large farms grazing on fields distant to farm buildings is more difficult resulting in a high grassland frequency in the rotation near the farm and a cash-crop rotation furthest away. It is important to determine N utilisation and environmental consequences of this. The results are also relevant for conventional farmers having ryegrass as the experiment includes a comparison between grass-clover and ryegrass.

Table A.1: Work package list (from application)

No.	Work package title	Participants*	Budget (1.000 DKK)	Start	End	Deliverable no(s):
1	Determination of precrop effects and nitrate leaching of grazed grassland rotations	<u>JE</u> , EMH	900	04/03	01/06	1, 2
2	Nitrate leaching on coarse sandy soils	<u>EMH</u> , JE	1.190	01/03	04/06	3
3	SOAR Ph.D. study: Mineralisation of grassland	<u>HHJ</u> , NN	200	07/03	07/06	4, 5
4	Optimising the N Cycle of organic dairy farms	<u>JE</u> , EMH, JEO, ISK, MA, HHJ	100	04/03	12/06	6, 7
Total			2.390			

* Responsible participants are underlined

B. Objectives and expected achievements

The objective of the project is to determine the importance of the grassland composition and frequency in the crop rotation for residual effects on yield and nitrate leaching during grazing and following ploughing in order to:

- increase the total N use efficiency of the crop rotation and reduce N leaching losses from dairy crop rotations
- suggest specific changes to management and rotation, that may be carried out in e.g. ni-

trate vulnerable zones within the short term, and

- establish a scientific sound basis for giving advise on these matters in both organic and conventional farming.

C. Midterm results and progress

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

The NIT_GRASS project started in 2003 and therefore only the early results can be presented at this stage. However, on the basis of experimental results in other parts of the DARCOF program (see section H. Critical reflection) new activities have already been included in the project. Below is a full description of the present activities. WP1 and WP4 contain the “original” activities (see application on www.okoforsk.dk/projekt/i15/ans.pdf) and WP2 and WP3 are the new activities now included in the expanded project (see Progress Report 2002 on www.okoforsk.dk/projekt/i15/stat02ny.pdf).

WP1: Determination of precrop effects and nitrate leaching of grazed grassland rotations

The experimental area in Foulum for investigating residual effects of grassland hosts this part of the project. Over the last 8 years, three crop rotations have been build up with different frequency of grazed grassland (Table 1) including both unfertilised grass-clover and fertilised pure ryegrass. In 2003 we have re-established grass-clover and ryegrass in all rotations and grazing in 2004 will follow this. In 2005 grasslands similar managed during the last three years (2002-2004) but with widely different grassland frequency in the rotation are ploughed out. In these crop rotations during 1997-2004 grazed grassland has been present 2, 3 and 6 times equivalent to 25, 38 and 75% of the crop rotation. Thus, the long-term effect of composition and frequency of grasslands can be studied in a block design with four replicates.

Table 1: Crop rotations at the experimental area in Foulum for investigating residual effects of grassland. In brackets is indicated the proportion of grassland in the rotation during 1997-2004.

Year	Rotation 1 (25%)	Rotation 2 (38%)	Rotation 3 (75%)
1994	1 st year grass	1 st year grass	1 st year grass
1995	2 nd year grass	2 nd year grass	2 nd year grass
1996	3 rd year grass	3 rd year grass	3 rd year grass
1997	Barley	Barley	4 th year grass
1998	Wheat	Wheat	5 th year grass
1999	Barley	Barley	6 th year grass
2000	Barley	1 st year grass	7 th year grass
2001	1 st year grass	2 nd year grass	8 th year grass
2002	Wheat	Wheat	Wheat
2003	Barley	Barley	Barley
2004	1 st year grass	1 st year grass	1 st year grass
2005	Barley	Barley	Barley

In the spring 2005 the combinations of grassland composition (grass-clover and ryegrass) and frequency (25, 38 and 75% grassland) are ploughed and within each of the four replicates in the block design are established four plots of 12 by 12 m with barley. The barley has ryegrass undersown as a catch crop. To determine precrop effects of N an adjacent reference area with-

without grassland history and with increasing mineral fertiliser N application is established for comparison of yields. To quantify other precrop effects than N and the yield potential for cereals following grassland, cattle slurry is applied to some of the grassland plots at ploughing. The same principles have been applied to the cereals in 2002 and 2003. In 2002 the pas-

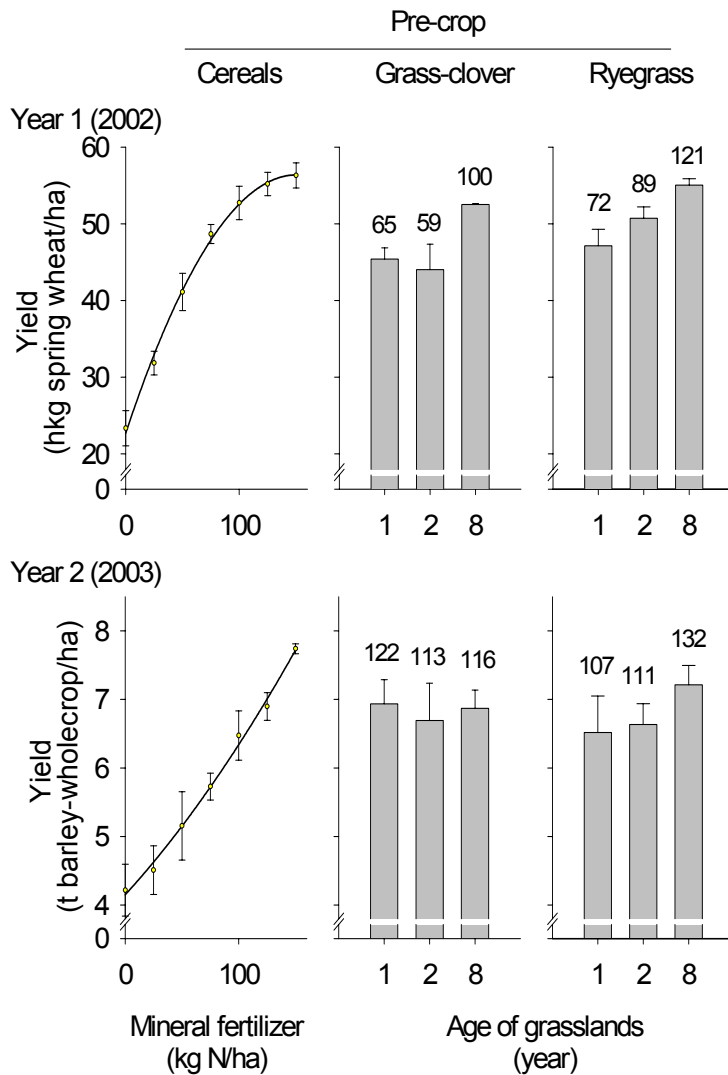


Fig. 1. Yield of spring wheat and barley-wholecrop in two years following ploughing of grasslands and compared to similar yields following a cereal history and with mineral fertiliser application. For cereals following grassland only unmanured plots are shown here. The number above the bar refers to the fertiliser replacement value of the grassland residual effect. Error bars: SE.

NB: Only 2003 data were funded by this project.

tures of grass-clover and ryegrass were ploughed after 1, 2 and 8 production years. As reference were used associated cut grassland and continuous 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. In 2003 the residual effect was even higher probably as a consequence of very low nitrate leaching in the winter 2002-2003, but this year differences between different grasslands seemed negligible.

In each of the 12 x 12 m plots are installed three ceramic suction cups at a depth of 1 m and 2 m apart, and every two weeks samples of soil water are collected by applying suction. The accumulated nitrate leaching is calculated after modelling the water balance. This method has been identified as the best practicable method for freely drained, structureless soils, which makes it suitable for this soil type. 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. Gener-

ally, nitrate losses were smallest following ploughing of young grass-clover swards only grazed for 1 year (6 kg NO₃-N/ha) and highest following ploughing of older swards grazed for 2 or 8 years (35 kg NO₃-N/ha). The results followed to some extent what would have been predicted by looking at the differences in pre-crop effect of the swards. It was 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.

In the coming years nitrate leaching will be determined in the year of grassland establishment, during grazing and following ploughing for the different combinations of grassland composition (grass-clover and ryegrass); frequency (25, 38 and 75% of crop rotation) and management following ploughing (4 levels of supplementary fertiliser).

WP2: Nitrate leaching on coarse sandy soils

On a dairy farm on coarse sandy soil were selected fields with different grassland history aiming at a minimum of bias caused by soil type and climatic conditions. The two fields were ploughed in spring 2003 and cropped with cereals in 2003 and 2004. The following factors are included in 2003. In 2004 are determined the residual effects.

Table 2: Treatments in the experiment on coarse sand.

Factor	Treatments
Accumulated N in grassland	<ol style="list-style-type: none"> 1. 5-year-old pasture in grass-rich rotation 2. 2-year-old pasture in cereal-rich rotation
Establishment of catch crops	<ol style="list-style-type: none"> 1. Spring barley with catch crop (Italian ryegrass) undersown – harvested green as fermented wholecrop 2. Spring barley with catch crop (perennial ryegrass) undersown – harvested at maturity 3. Spring barley without catch crop – harvested at maturity
Fertilisation of barley following grassland	<ol style="list-style-type: none"> 1. No fertiliser 2. Low fertiliser application (60 kg NH₄-N ha⁻¹ in cattle slurry) 3. Moderate fertiliser application (120 kg NH₄-N ha⁻¹ in cattle slurry)

In the experimental period is used best management practice regarding other factors that may influence N use efficiency. The experiment contains four replicates of each combination of treatments and 2 ceramic suction cups are installed at 1 m depth in selected plots for determination of nitrate leaching. Suction cups are installed in all plots without fertiliser application and selected plots with fertiliser application. Nitrate leaching is determined in the two years from 1 April to 31 March with termination in 2005. Prior to ploughing of grasslands quantity and chemical composition of above- and below-ground plant material was determined. Yield and N-uptake of all crops are determined. From available data is constructed N balances for grasslands prior to ploughing and for cereals after ploughing.

The effect of a perennial ryegrass catch crop on yield of spring barley harvested at maturity was insignificant for both grain and straw. However, grain yields showed a significant effect of N application after the 2-year-old pasture while no effect of N application was observed after the 5-year-old pasture. Increasing the N application from “Low” to “Moderate” tended to increase yield in the 2-year-old pasture but the increase was not significant. These facts imply that more readily-available N was present after the 5-year-old than after the 2-year-old pasture. Yields of fermented wholecrop increased with increasing N application on both

fields, but the increase from “Low” to “Moderate” was not significant.

Table 3: Yield of barley and fermented wholecrop following ploughing of 5-year-old and 2-year-old pastures. No significant interactions between Crop and N application was found.

	Barley		Fermented wholecrop ^{*1}	
	Grain ^{*2} , hkg ha ⁻¹	Straw dm, hkg ha ⁻¹	Barley and grass dm ^{*3} , hkg ha ⁻¹	1. cut of grass dm ^{*4} , hkg ha ⁻¹
5-year-old pasture				
Crop				
Without catch crop	46.8	48.8	-	-
With catch crop	45.4	52.0	-	-
Early wholecrop ^{*2}	-	-	-	-
LSD _{.95}	ns	ns	-	-
N application				
No	45.7	45.6 ^b	46.1 ^b	36.3
Low	47.5	49.2 ^b	61.0 ^a	41.9
Moderate	45.0	56.4 ^a	66.3 ^a	41.3
LSD _{.95}	ns	4.0	11.8	ns
2-year-old pasture				
Crop				
Without catch crop	44.4	35.1	-	-
With catch crop	44.0	35.5	-	-
Ferm. wholecrop ^{*1}	-	-	-	-
LSD _{.95}	ns	ns	-	-
N application				
No	39.7 ^b	25.7 ^b	28.8 ^b	26.1
Low	45.0 ^a	38.4 ^a	48.3 ^a	24.8
Moderate	48.0 ^a	41.8 ^a	57.5 ^a	31.4
LSD _{.95}	5.1	4.0	10.0	ns

Within each factor and column, means followed by the same letter are not significant different from each other.

*1 Barley and grass harvested at beginning of heading

*2 85% dry matter. Harvested on 11 August 2003 at maturity

*3 Harvested on 17 June 2003

*4 Harvested on 15 August 2003

The lack of response to fertiliser application following ploughing of the 5 year old pasture indicates that N mineralisation was very high and we consider the selected fields ideal for investigating the possibilities for preventing nitrate leaching on this soil type.

WP3: SOAR Ph.D. study: Mineralisation of grassland nitrogen

Possibilities of improving the N use efficiency of grasslands on sandy soils are investigated. Detailed planing of this WP awaits the engagement of the Ph.D. student, which is still in process.

WP4: Optimising the N cycle of organic dairy farms

At the end of the project all the data that has been collected from the experimental area since

establishment of the different grasslands in 1994 will be included in a summarising exercise. This includes N-uptake and nitrate leaching effects from the arable and grassland phase of the crop rotation caused by differences in grassland history, age and frequency – all of which has been combined with unfertilised grass-clover and fertilised ryegrass. Furthermore, N₂-fixation and denitrification has occasionally been determined as well as the N-balance of grazing cows. All this information will be used for constructing crop rotation N-balances and make simple scenarios for the effects of different crop combinations/frequencies. The effect of different management on the experimental area will be related to investigations from practical farms where the overall balance are known and to the results of the model exercises going on in other DARCOF projects. Such simple calculations based directly on experimental results are notoriously useful in the advice of farmers.

Time schedule

The project started in 2003, when grasslands were established as undersown in a cereal followed by grazing in 2004. In 2005 grasslands are ploughed. WP1 runs from establishment in 2003 until the end of drainage in April 2006, WP2 runs from ploughing of grasslands in 2003 and until the end of drainage April 2005. The Ph.D. study in WP3 will start during 2003. WP4 (optimising the N cycle) is continuously developed through the whole project. Deliverables and Milestones will be fulfilled at the end of the project in Jan-May in 2006.

C.2 Fulfilment of deliverables and milestones

(To be completed for each work package)

WP number and title	Time schedule according to application	Deviations, if any*
Deliverables		
1 Paper on precrop effects of combinations of grass-clover/ryegrass and different frequencies of grassland in the rotation submitted for international reviewed journal.	Jan 2006	
2 Paper on nitrate leaching from different grassland rotations submitted for international reviewed journal.	May 2006	
3 Paper on nitrate leaching and management options on coarse sandy soils submitted for international reviewed journal	May 2006	
4 Ph.D. study on grassland nitrogen initiated.	July 2003	Dec 2003
5 Ph.D. study completed	July 2006	
6 Paper on nitrogen management in dairy farming systems published in farmers magazine.	Jan 2006	
7 Paper on environmental consequences of ploughing different grasslands published in farmers magazine.	May 2006	
Milestones		
1 The effect of soil type, grassland composition and frequency in crop rotations on precrop effects following ploughing has been determined.	Jan 2006	
2 The environmental consequences of grassland composition and frequency in the rotation has been determined.	May 2006	

** Deviations are to be further discussed in D*

D. Description of deviations and subsequent adjustments of plans

The engagement of the Ph.D. student is still in process.

E. Project publications and other products

1. Articles in international, scientific journals with review procedures
2. Papers presented at congresses, symposiums, etc.

Eriksen J. and Vinther F.P. (2003) Nitrate leaching and N₂-fixation in grasslands of different composition, age and management. Book of abstracts 12th N Workshop, Exeter UK, 21-24 September.

3. Reports, articles in agricultural journals, etc.

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

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

Jørgen Eriksen and Margrethe Askegaard presented a poster on “Nitrogen management in the organic dairy crop rotation” at the organic field day in Foulum, June 12, 2003.

Jørgen Eriksen gave a presentation on “The effect of catch crops on the supply of N and S in organic crop rotations” at the Organic field course in Årslev on June 19, 2003.

F. Scientific education

The project includes part of a Ph.D. study planned to start in 2003 and a Master student have been associated from February 2003: Jens Prior Hansen M.Sc. project: Residual effect of ploughing out grasslands as a function of grassland age, management and fertilisation.

G. National and international cooperation

The project has a life of its own, but it is also an integrated part of other activities in the DARCOF programme and in international programmes. This includes:

- DARCOF project VII.12 will intensively be using the experimental area for detailed studies on leaching of dissolved organic carbon, denitrification and simulation using the DAISY model. The two projects will work in close collaboration experimentally and in the interpretation of data (Contact: Ole H. Jacobsen, DIAS).
- DARCOF project VII.16 will be using the experimental area in communication of results from organic farming research to practical farming (Contact: Jørgen E. Olesen, DIAS).
- DARCOF project I.4 uses the area in research for increased quality of wheat for bread-making (Contact: Bent T. Christensen, DIAS).
- DARCOF project I.13 uses the area for determination of N₂-fixation of grass-clover and denitrification from grazed grassland (Contact: Per Ambus, RISØ).
- DARCOF project I.3 will be using data from the experimental area for modelling N cy-

cling in organic farming systems (Contact: Jørgen E. Olesen, DIAS).

- The EU-project “Greenhouse Gas Mitigation for Organic and Conventional Dairy Production (MIDAIR)” will be using the two grassland types present in a block design on the area (Contact: Søren O. Petersen, DIAS).
- The project leader and project staff are involved in collaboration with a range of European partners through the EU-COST-action 627 “Carbon Storage in European Grasslands” and 852 “Exploiting the Agronomic Potential of Forage Legumes in Contrasting Environments of Europe”.

The results from other projects are continuously being exchanged and this synergy of more projects and many results from the same system improves the opportunity of reaching the objectives of the present project.

H. Critical reflection on the project

Results from different projects within the DARCOF framework indicated that nitrate leaching on coarse sandy soils might constitute a substantial problem. Although the NIMAB project showed that nitrate leaching following the ploughing of grassland could be controlled on sandy loam soil the EX_UNIT project and measurements on private farms in the BIO_MOD project indicated large losses on coarse sandy soils. Keeping in mind that a major part of organic dairy farming is located on coarse sandy soils, the previous experimental work within DARCOF may not have been representative. Therefore, at this stage it is not clear whether the recommended management following grassland ploughing is sufficient to avoid large leaching losses from these soils. In order to overcome this, a new experiment has now been initiated on coarse sandy soil (WP2) and a Ph.D. study is associated with this. It is our expectation, that this expansion of the NIT_GRASS project will provide a better possibility for generalising results from the DARCOF projects.

Recently, it has been reported, especially in the UK, that leaching may not only be restricted to nitrate in grasslands but also some dissolved organic nitrogen has been found in leachates. Whether this is relevant to lighter soils under Danish conditions may be questioned but to get some indication measurement of dissolved organic N will be carried out in leachates from the coarse sand.

We have experienced that the, for the reductions of nitrate leaching, successful catch crop strategy has a down side at some sites: The development of weed problems, especially with thistle. Although some weed control has been carried out between sowing of cereal and sowing of catch crops in the cereals, this may not always be efficient. We will consider before the ploughing out of grassland in WP1 in 2005 to use more severe weed control, such as sowing at double distance and hoeing. As this may affect negatively the tightness of the N cycle it must be considered if the can be investigated experimentally.

8. Budget

A. Account for any change in budgets

Two scientific man-months and 93,000 kr in operational costs has been moved from 2003 to 2004.

B. Budget for the whole project (1.000 DKK)

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

Year:	Consumption before 2003	Expected consumption 2003	2004	2005	2006	Total
Man-months	0	6.75	7.5	13	4	41,5
Scientific personnel	0	1.25	10.75	8	2	22
Technical personnel	0	5.5	7	5	2	19.5

Year:	Consumption before 2003	Expected consumption 2003	2004	2005	2006	Total
Salaries	0	217	671	577	173	1,638
Scientific personnel	0	61	460	406	104	1,032
Technical personnel	0	156	210	171	69	606
Other operational costs	0	22	205	97	29	680
Equipment						
Others (please specify)						
Direct costs	0	239	876	674	202	1,991
Indirect costs (20% of direct costs)	0	47	176	135	41	399
Total	0	286	1,052	809	243	2,390

Comments:

9. Signatures and stamps

Name	Institute	Date	Signature
Jørgen Eriksen	Danish Institute of Agricultural Sciences		

Appendix I. Detailed budget

A. Budget for each participating institute (1.000 DKr)**NIT GRASS Danish Institute of Agricultural Sciences**

Year:	Consumption before 2003	Expected consumption 2003	2004	2005	2006	Total
Man-months	0	6.75	3	13	4	37
Scientific personnel	0	1.25	6.25	8	2	17.5
Technical personnel	0	5.5	7	5	2	19.5

Year:	Consumption before 2003	Expected consumption 2003	2004	2005	2006	Total
Salaries	0	217	536	577	173	1,503
Scientific personnel	0	61	326	406	104	897
Technical personnel	0	156	210	171	69	606
Other operational costs	0	22	173	97	29	648
Equipment						
Others (please specify)						
Direct costs	0	239	709	674	202	1,824
Indirect costs (20% of direct costs)	0	47	143	135	41	366
Total	0	286	852	809	243	2,190

Comments:

A. Budget for each participating institute (1.000 DKr)**NIT GRASS Royal Veterinary and Agricultural University**

Year:	Consumption before 2003	Expected consumption 2003	2004	2005	2006	Total
Man-months			4.5			
Scientific personnel			4.5			
Technical personnel						

Year:	Consumption before 2003	Expected consumption 2003	2004	2005	2006	Total
Salaries			135			
Scientific personnel			135			
Technical personnel						
Other operational costs			32			
Equipment						
Others (please specify)						
Direct costs			167			
Indirect costs (20% of direct costs)			33			
Total			200			200

Comments: This project only in part funds the Ph.D. study and is therefore used in 2004.