



## Annual Status Report 2001 and Application for Continuation in 2002

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

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### 1. Research program

Research in organic farming 2000-2005 (DARCOF II)

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### 2. Project title and number

I.13 Dinitrogen Fixation and Nitrous Oxide Losses in Organic Grass-Clover Pastures: An Integrated Experimental and Modelling Approach (DINOG)

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7. **Start of project:** 2000  
**End of project:** 2004
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## 8. Annual report/Application for continuation in 2001

### A. Objectives and expected achievements (from application)

The proposed work will investigate magnitudes and describe characteristics of N<sub>2</sub>O emissions, denitrification and N<sub>2</sub> fixation in organically managed grass-clover pastures under different grazing intensities and variable soil textures. The results will be implemented in submodules of a whole-farm N flow model. In particular the objectives of the work are to:

- investigate and elucidate relationships between gross rates of mineralisation and nitrification and losses of N<sub>2</sub>O and N<sub>2</sub>
- investigate the translocation and fate of biologically fixed N<sub>2</sub> with emphasis on gaseous losses and the accompanying plant uptake
- determine the total N<sub>2</sub> fixation including the contribution from stolons and roots
- estimate N input through N<sub>2</sub> fixation, and gaseous N losses through N<sub>2</sub>O emission and denitrification under field conditions
- adapt, parameterise and validate a soil-plant-atmosphere model of nitrogen turn-over for simulation of N<sub>2</sub>O emission, including simulation of spatial variability caused by urine and dung patches on grazed pastures

In order to meet these goals, a number of field experiments will be initiated at the organic farming experimental trials of Research Centre Foulum. These activities will be supplemented by microcosm experiments under fully controlled conditions at the Risø National Laboratory. Results from the experimental activities will be made available for incorporation into the FASSET whole-farm model.

Organic farming practices, and in particular dairy production systems, are becoming increasingly abundant within Danish agriculture. In Denmark, grass-clover pastures are predominantly located on sandy soils, and data on N<sub>2</sub> fixation from these soils are very sparse. Therefore, the information provided by this project will be a significant support for decision making by local and regional organic farming extension services. Data from this work also provides information necessary for a holistic evaluation of the environmental impact of organic farming practices, and it will supply very useful information for the construction of national and regional inventories of greenhouse gas emissions.

## B. Project summary (from application)

Organic farming practices, and in particular dairy production systems, are becoming increasingly abundant within Danish agriculture. Grazed pastures may be a significant source of nitrous oxide (N<sub>2</sub>O), an important greenhouse gas, and data in the literature suggest that N<sub>2</sub>O emissions from e.g. organic dairy farms may be smaller than from conventional systems. The difference in N<sub>2</sub>O emissions, however, may depend on the intensity with which dinitrogen (N<sub>2</sub>) fixed by the legumes in grass-clover mixtures are recycled in the grazed fields. Particularly urine induces N<sub>2</sub>O emissions, which also constitutes a major loss of N.

Dinitrogen fixation in grass-clover pastures is influenced by grazing and excretal deposits, which thus needs to be taken into account when estimating total N<sub>2</sub> fixation. Secondly, hitherto total N<sub>2</sub> fixation estimates usually has not accounted for contributions from plant compartments below grazing-height, which causes a severe bias in estimates on N<sub>2</sub> fixation.

The IPCC guidelines for making inventories of greenhouse gases recommend a N<sub>2</sub>O release rate of 1.25% for all N inputs, including N<sub>2</sub> fixed by legumes. Because of the uncertainties in quantifying N<sub>2</sub> fixation, no contribution from N<sub>2</sub> fixation to N<sub>2</sub>O emissions from legume pastures has actually been estimated so far. Inventories of N<sub>2</sub>O emissions for organic farming systems may therefore be severely biased.

The proposed work will investigate magnitudes and describe characteristics of N<sub>2</sub>O emissions, denitrification and N<sub>2</sub> fixation in organically managed grass-clover pastures under different grazing intensities and variable sandy soil textures. Quantitative results will be implemented in submodules of a whole-farm N flow model. To meet these goals a number of field experiments will be initiated at organic farming experimental trials, supplemented by microcosm experiments under fully controlled conditions.

The information provided by this project will (i) provide information necessary for a holistic evaluation of the environmental impact of organic farming practices, (ii) be a significant support for decision making by local and regional organic farming extension services, and (iii) supply very useful information for the construction of national and regional inventories of greenhouse gas emissions.

**Table 1: Work package list (from application)**

No.	Work package title	Participants*	Budget (1.000 DKr)	Start	End	Deliverable No:
1.1 – 1.2	Process studies of nitrogen exchange between soil and atmosphere	<u>Risø</u> DIAS	1454	11/00	05/04	D1.1-1.7 Project1-3
2.1 – 2.3	Field studies of nitrogen exchange between soil and atmosphere	<u>DIAS</u> Risø	1816	01/01	05/04	D2.1-2.6 Project1-3
3	Modelling of nitrogen exchange between soil and atmosphere	<u>DIAS</u> Risø	390	10/02	05/04	D3.1-3.2 Project2-3

\* Responsible participants are underlined

## C. Progress

### C.1 Annual description (resume) of main results and conclusions

#### *WP 1.1: Gross N turnover and losses of N<sub>2</sub>O and N<sub>2</sub>*

The relationship between gross N mineralisation and nitrification, respectively, and N<sub>2</sub>O and N<sub>2</sub> emissions have been investigated in the first year. Monoliths were established in March in grass-clover fields at Foulum (Burrehøjvej) comprising 1<sup>st</sup>, 2<sup>nd</sup> and 8<sup>th</sup> year trials. At four times during the

season, April, June, August and October sets of monoliths were collected for transportation to Risø National laboratory where labelling with  $^{15}\text{N}$  took place. Following labelling evolution of  $^{15}\text{N}$  in evolved  $\text{N}_2\text{O}$  and  $\text{N}_2$  was analysed simultaneously with analysis of  $^{15}\text{N}$  contents in inorganic and organic soil pools. In order to handle the high number of injections of  $^{15}\text{N}$ -solutions into the root zone necessary to meet assumptions about homogeneity we developed a semi-automatic injection system based on the use of a Hamilton precision liquid processor.

Soil and soil-solution samples have been collected from the three first sampling events and are pending analysis. All gas analysis from the three first samplings has been completed. The October sampling has not yet been undertaken.

A preliminary examination of the gas data shows marked emissions of  $\text{N}_2\text{O}$  from the soil monoliths, which in all cases responded to the injections of  $^{15}\text{N}$ -solutions.

*WP 1.2:  $\text{N}_2$  fixation,  $\text{N}_2\text{O}$  emission and N translocation in  $^{15}\text{N}_2$ -labelled soil-plant systems.*  
This activity has been initiated in September of 2001 when a Ph.D.-student joined the project.

*WP 2.1:  $\text{N}_2$  fixation: Contribution from stolons and roots*

Plots for estimating total  $\text{N}_2$  fixation, including the contribution from roots and stolons, were established shortly after sowing spring barley undersown with grass-white clover on a coarse sandy soil (Jyndevad) and a sandy loam soil (Foulumgård). The first harvest will take place in November 2001.

*WP 2.2: Field estimates of  $\text{N}_2$  fixation in grass-clover*

Effects of age on  $\text{N}_2$  fixation have been studied in a field trial with a 1<sup>st</sup>, a 2<sup>nd</sup>, and an 8<sup>th</sup> year grass-clover (Burrehøjvej). Preliminary results indicate lowest production rates in the 8<sup>th</sup> year grass-clover and the 2<sup>nd</sup> year grass-clover tended to have highest production rates of clover. The harvested plant material has not yet been analysed for  $^{15}\text{N}$ , and results on  $\text{N}_2$  fixation rates are not available.

At two commercial farms, where  $\text{N}_2$  fixation in grass-clover pastures has been indirectly estimated at regular intervals by harvesting plots that have not been exposed to grazing between samplings. The preliminary results from these measurements generally show low production rates, and consequently low  $\text{N}_2$  fixation rates. The  $\text{N}_2$  fixation in the harvested biomass will probably be lower than  $50 \text{ kg N}^{-1}$  for the entire growing season.

*WP 2.3 Spatial variation and field estimates of  $\text{N}_2\text{O}$  emission*

The objective of this first experimental year has been to characterize the relationships between urine deposition and soil conditions, respectively, and  $\text{N}_2\text{O}$  emissions. The work has included description of spatial and temporal dynamics of  $\text{N}_2\text{O}$  emissions and soil conditions during grazing and evaluation of N deposition patterns by remote sensing.

The spatial distribution of  $\text{N}_2\text{O}$  emissions was examined on two separate days in June and August, respectively, following a 6-d grazing period. The pasture under study included 1-, 2- and 8-year old sections, and in total 99 measurement points were marked in a grid pattern across these plots. Nitrous oxide fluxes were measured from 33 randomly selected points, while soil samples were taken in all 99 points and analyzed for soil moisture, inorganic N, urea-N, dissolved organic C, electrical conductivity and pH.

To examine the temporal dynamics of  $\text{N}_2\text{O}$  emissions and soil chemical composition following urine deposition, as well as possible interactions between N input and  $\text{N}_2\text{O}$  emission, a microplot experiment was conducted in June, which included the following treatments: i) no application, ii) normal urine (2.5 kg per  $0.6 \text{ m}^2$ ), iii) normal urine (5 kg per  $0.6 \text{ m}^2$ ), and iv) urine (2.5 kg per  $0.6 \text{ m}^2$ ) enriched with urea. Nitrous oxide emissions were measured and soil samples taken after 0.3, 1, 2, 4, 6, 10 and 16 d; soil analyses corresponded to those described above. Also, remote sensing monitored absorbance of photosynthetic light as an index of grass growth. A similar experiment was initiated in late September, which includes treatments i), ii) and iv). A colleague from Institute of Grassland and Environmental Research, North Wyke in UK joined the experiment, and the scope of this second microplot experiment was extended to also address the associated microbial dynamics and mechanisms behind  $\text{N}_2\text{O}$  emissions.

A test for effects of root damage on  $\text{N}_2\text{O}$  emission measurements was conducted in early June.

Urine and dung deposition will stimulate grass growth. In the pasture this is visible as patches of a darker green color. We are currently examining if remote sensing from 150 m height will enable identification of urine spots and dung pats from larger sections of the pasture.

## C.2 Fulfilment of tasks and deadlines in individual work packages

(To be completed for each work package)

<i>WP1: Process studies of nitrogen exchange between soil and atmosphere</i>	Time schedule according to application	Deviations, if any*
Task		
1.1 <i>Lysim. N<sub>2</sub> fixation</i>	00 – 02	01 – 03
1.2 <i>Gross N turnover</i>	01 – 03	
Deliverables		
D 1.1	05/01	03/02
D 1.2	06/01	
D 1.3	12/01	10/02
D 1.4	09/03	
D 1.5	05/04	
D 1.6	05/04	11/03
D 1.3	03/02	
Milestones		
M 1.1	05/01	03/02
M 1.2	06/01	
M 1.3	08/02	06/03
M 1.4	10/03	
<i>WP2: Field studies of nitrogen exchange between soil and atmosphere</i>		
Task		
2.1 <i>Contribution from stolons and roots</i>	01 – 03	
2.2 <i>Field estimates of N<sub>2</sub> fixation in grass-clover</i>	01 – 03	
2.3 <i>N-emission from grass-clover pastures</i>	01 – 03	
Deliverables		
D 2.1	11/01	01/03
D 2.2	05/04	
D 2.3	07/02	07/03
D 2.4	05/04	
D 2.5	05/04	
D 2.6	03/02	
Milestones		
M 2.1	12/01	12/02
M 2.2	10/03	
M 2.3	10/03	
<i>WP3: Modelling of nitrogen exchange between soil and atmosphere</i>		
Task		
3.1 <i>Revise N<sub>2</sub>O sub-model</i>	02 – 03	
3.2 <i>Verification and validation</i>	03	
Deliverables		
D 3.1	02/03	
D 3.2	05/04	
Milestones		
M 3.1	02/03	
M 3.2	02/03	
M 3.3	11/03	

\* Deviations are to be further discussed at C3

### **C.3 Discussion on the progress, incl. deviations and achievements in the project as a whole and in the individual work packages**

During the growth season of 2001 the experimental work within the project has progressed substantially with focus on experimental set-up and method developments. Until now the work has concentrated on the experimental work, and limited time has been available for data analysis and evaluation. A number of experimental methods have been developed beneficial for the future work in the project as well as for other research teams interested in N-dynamics in grass-clover systems. For technical as well as logistical reasons it has been necessary to adjust time-schedules for two distinct activities in the project, however, overall goals and budgets are maintained.

*WP 1.1:* In contrast to the initial planning, suggesting one-two measurement campaigns, activities were intensified during the 2001 season in order to achieve seasonal series of gross N dynamics and gaseous N-losses in 1<sup>st</sup>, 2<sup>nd</sup>, and 8<sup>th</sup> year grass-clover the Burrehøjvej trial. This was decided due to the availability of the Burrehøjvej trials, and secondly due to the reduced activity level in *WP 1.2*. The completion of D 1.6 is consequently advanced by 6 months.

*WP 1.2:* The development of a method for studying <sup>15</sup>N<sub>2</sub> fixation in grass-clover monoliths has been impeded by delayed delivery of analytical instrumentation and technical problems with the supplied instruments. A fully operative system was not available until July of 2001, and it was therefore decided to postpone this activity until 09/01 when a Ph.D.-student joined the project. As a consequence deliverables D 1.1 and 1.3 and milestones M 1.1 and 1.3 are postponed for 10 months.

*WP 2.1 – 2.3:* In the growing season 2001 a field trial at Burrehøjvej, Foulum with a 1<sup>st</sup>, a 2<sup>nd</sup>, and a 8<sup>th</sup> year grass-clover was available. These trials have been the experimental sites for *WP 1.1* and *WP 2.2 – 2.3*, and although not originally planned, measurements of N<sub>2</sub> fixation were carried out, giving the opportunity of studying the effect of grass-clover age on N<sub>2</sub> fixation and the possibility of obtaining a complete N-balance for these trials. Consequently, the experiments for studying effects of grazing and urine deposition on N<sub>2</sub> fixation, which were planned for this season, has been postponed to the 2002-growing season. This implies that deliverables D 2.1 and D 2.3, as well as milestone M 2.1 are postponed for one year.

### **D. Description of plans and future work in the project as a whole and in the work package (Including plans for publication and communication)**

The project group will have a meeting in December of 2001 in order to discuss results achieved in 2001 and to further identify and narrow questions, which will be addressed in the experimental activities for 2002.

The work in *WP 1.1 & 1.2* will continue in 2002 with focus on the effects of urine on grass-clover rhizosphere N-turnover. The results from 2001 and 2002 will be presented at the 12<sup>th</sup> N-workshop in 2003 and in an international publication.

The measurements of <sup>15</sup>N<sub>2</sub> fixation and <sup>15</sup>N<sub>2</sub>O emissions will be carried out as proposed, but with a delay as stated above in C3.

*WP 2.1 & 2.2:* The study on effect of grass-clover age on N<sub>2</sub> fixation will be ended by the end of this year and results presented at the "European Grassland Conference" in France in April 2002.

The study on contribution of stolons and roots to total N<sub>2</sub> fixation (*WP 2.1*) will be continued as planned with the first harvest in late autumn 2001.

A field trial for studying the effects of grazing and urine deposition on N<sub>2</sub> fixation will be established in the spring 2001 and measurements continued throughout the growing season.

WP 2.3: If urine spots and dung pats can be identified by image analysis, this approach will be extended in the next grazing season. Nitrous oxide emissions will also be quantified in campaigns, but the exact strategy for these campaigns, i.e., whether they will focus on individual urine spots or randomly distributed measurements, has not yet been decided.

An international publication is planned on the basis of the urine spot experiment from September 2001.

## **E. Project publications**

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

### **2. Presentations at congresses, symposiums etc.**

Petersen, S.O. (2001) Nitrous oxide emissions from grasslands. Poster presented at EU Concerted Action 627 meeting in Dublin, 7-8 April 2001.

### **3. Articles in agricultural journals etc.**

### **4. Other presentations at meetings, field days etc.**

Presentation of experimental site in connection to workshop at Foulum within EU Concerted Action 627 'Carbon Storage in Grasslands', 29 Sept 2001.

Thyme, M. (2001) Nitrous oxide emissions in grass-clover fields. Oral presentation at the Ph.D. summer school on "*Linking Ecology and Organic Farming*", organised by SOAR (Research School for Organic Agriculture and Food Systems), Kongskilde Friluftsgaard, 24-28 September 2001.

## **F. Scientific education (Ph.D. and post doc.), including visiting scientists and visits abroad**

WP 1.1 & 1.2 (Risø): M.Sc. Mette Thyme joined the project as Ph.D.-student beginning 15 September 2001. The Ph.D.-project receives funding by DARCOF II, The Danish Research Councils and Risø National Laboratory.

WP 2.3: Visit in the period 18-27 Sept 2001 by Dr. Roland Bol, Institute of Grassland and Environmental Research.

Martin Nørgaard Hansen, Dept. Agricultural Engineering, DIAS (Ph.D. student) participates in a microplot study with measurements of ammonia volatilisation.

## **G. National and international co-operation**

The activities in WP 1 and WP 3 are closely linked to a newly started EU-project GREEN'GRASS on greenhouse gas emissions from European grasslands. The project has participants from 7 countries and is joined by Per Ambus and Jørgen E. Olesen.

### *WP 2.3*

Dr. Roland Bol, IGER

Dr. Peter Roslev, Aalborg University

Dr. Klaus Dittert, University of Kiel

