**Title: I.4 NItrogen MAnagement and cropping methods for enhanced Bread wheat production**
**Acronym: I.4 NIMAB**
**Date: 2 August 2000**

## 1. Summary

The demand for organically produced grain for bread considerably exceeds Danish farmers' production. Thus, nearly 70% of the consumed organically grown bread wheat is imported. 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.

## 2. Research group

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## 3. Introduction

Organic cropping systems based on rotations with grass/clover pastures and abundant recycling of organic matter accumulate significant quantities of labile organic nitrogen (N) in the soil. Nevertheless, the availability of N often limits yields of short-season crops without $N_2$-fixing ability. While the N mineralization rate in the early growth stages is less than crop uptake potentials, mineral N may accumulate in the soil during later growth phases. The build-up of excess mineral N late in the growing season may enhance leaching losses of nitrate in the following autumn and winter period unless other measures to conserve labile N are introduced in the soil/plant system.

A basic aim in organic farming is therefore 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.

Grazed grass/clover pastures accumulate considerable amounts of N, the build-up of N in the system depending on fertilization rate, stocking density, off-field feeding intensity of the grazing animals, period of grazing and the age and botanical composition of the sward. Cropping systems incorporating grazed pastures are prone to leaching losses of nitrate because their ploughing under is followed by a substantial increase in the N mineralization capacity of the soil. Carefully designed cropping sequences after termination of grazed grass/clover fields are mandatory to retain N and to exploit the enhanced release of mineral N in producing quality cereals with a high protein content such as wheat for breadmaking.

On farms without livestock, the production of protein-rich cereals depends on a sufficient supply of N derived from $N_2$-fixing grain crops and green manures and on N in imported animal manure. These cropping systems are particularly prone to N limitation, accentuating the need to manipulate the competition between crop and weeds for plant available N. Possible means of improving the competitive ability of cereal crops includes banding of animal manure by direct incorporation according to a specific placement geometry, selection of cultivars with enhanced early root development and N uptake, and adaptation of soil tillage strategies that control the weed and accelerate soil N mineralization. Additional measures include intercropping of $N_2$-fixing green manures and cereals, the strips of green manures being incorporated in the early summer period in order to supply mineral N to the developing cereal crop.

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.

Breadmaking quality is related to the protein and gluten contents. Organically grown wheat tends to have a lower protein content than conventionally produced wheat providing sub-optimal 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 this project is to improve the N management and the cropping methods in organic plant production in order to enhance the quality of bread wheat and to increase the production volumen while improving the N-use efficiency and reducing the N loss by leaching. More specifically the work focuses on:

- utilization of N in grazed grass/clover pastures
- soil tillage strategy and organic matter management for improved N use efficiency
- crop and weed competition and N uptake as affected by manure placement
- bread wheat quality as affected by crop variety and N management

## 4. State of the art

### 4.1 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 (Prins, 1980). Consequently, nitrate leaching following cut grass is often very low (Simmelsgaard, 1998). 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 (Whitehead, 1995), 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 (Cuttle and Scholefield, 1995).

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 were 50% lower in the newly reseeded fields compared to permanent pasture, averaged over the first five years after reseeding (Scholefield *et al.*, 1993). There is some uncertainty as to when the N equilibrium is reached. In a non-grazed system Johnston *et al.* (1994) found that N accumulation apparently reached a maximum in 3rd year grass/clover.

The ploughing of grassland is followed by a large increase in the mineralisation rate of N, and a well-organized crop rotation is important in order to utilize this huge pulse of N released (Eriksen *et al.*, 1999, Francis, 1995). In the DARCOF programme 1 it was shown that the release of N following the ploughing of 3rd year grass/clover could by controlled with good management (spring ploughing and use of catch crops). Thus, substantial precrop effects were observed in two years after ploughing without increased leaching losses. Because of the huge precrop effects this is the 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. This may increase the risk of nitrate leaching.

In this project the N dynamics are investigated in grazed pastures where the N pool is building up ($1^{st}$ and $2^{nd}$ year) and where it has reached equilibrium (6-8 years). Nitrate leaching is determined in grazed grass/clover in the pasture phase and in the years following ploughing. It is investigated how different combinations of precrop effect and organic fertilizer use affect the breadmaking quality of spring wheat and the nitrate leaching losses.

This project aims at improving the basis for deciding the frequency of grass/clover fields in dairy crop rotations regarding age at ploughing and years between ploughing and reseeding. Furthermore, it is the aim to clarify and solve the potential conflict between optimizing grain nitrogen content and minimizing nitrate leaching.

### 4.2 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 (Myers *et al.*, 1997), 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.

It has been shown that 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 (Hansen & Djurhuus, 1997; Stenberg *et al.*, 1999), indicating that significant quantities of 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 although Powlson (1980) found slightly faster N mineralization rates following cultivation in the summer period.

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. Physical protection of labile organic matter is associated with the presence of fine soil particles (Christensen, 1996), and clayey soils probably exhibit a greater potential for accommodating physically protected labile N than coarse sand soils.

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. The overall aim must be to devise tillage strategies that simultaneously optimize the various tillage-dependent management parameters.

### 4.3 Crop and weed competition and N uptake as affected by manure placement

Placement of mineral fertilizer in bands parallel to the seed row increases the nutrient uptake, the increase of N in a small grain crop being most pronounced early in the elongation phase (Kaila & Elonen, 1970). Similarly, banding of mineral N below the seed row may increase the $^{15}$N-recovery in the crop during the elongation phase (Hartman & Nyborg, 1989). About 2/3 of maximum $^{15}$N-recovery occurs during an almost linear uptake phase of 7 days (Petersen, submitted). The start of the linear uptake phase was delayed 0.5 day $cm^{-1}$ increased distance between the row of growing spring wheat and the mineral fertilizer band.

The beneficial effect of banding depends on soil nutrient status. The yield increase appears more significant in poor crop rotations (Lyngstad, 1977) and in low fertility soils (Ekeberg, 1977; Alston, 1980). Similarly, a high N immobilisation potential may increase crop N uptake from added fertilizer (Carter & Rennie, 1984). 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 (Sørensen & Jensen, 1995). The reduced immobilization due to banding of mineral N can be reflected in an increased crop N uptake (Tomar & Soper, 1987).

Banding of added nutrients may also be effective in managing weeds when combined with other methods of weed control (Kirkland & Beckie, 1998). Banding of NPK-fertilizer increased the effect of weed harrowing in spring barley compared with surface applied fertilizer (Rasmussen *et al.*, 1996). Banding of animal slurry in organic cropping systems may present a similar positive effect in relation to weed/crop competition and increased N use efficiency. On-going studies indicate that dry matter production and $^{15}$N-recovery in crop and weed during the crop elongation phase can be affected by placement depth of the slurry band. Similar results were obtained in an experiment using mineral N ; the effect of distance between the crop row and fertilizer band was most pronounced during the linear uptake phase, whereas the maximum $^{15}$N-recovery at ear emergence was not significantly affected by the distance (Petersen, submitted). Thus, the effect of banding animal slurry was mainly expressed over a short period of 2-4 weeks in the initial elongation phase.

Recent studies in the DARCOF programme 1 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. The main conclusions were that crop/weed competition and weed harrowing could be improved, crop types and actual weed species having a major influence on the results. Due to earlier emergence, faster initial growth and earlier response to slurry injection barley performed better than oat (Rasmussen, submitted). In experiments with spring wheat, increased nutrient application is seen to both reduce (Franke, 1998) and increase competitive ability of the crop (Nakoneshny & Friesen, 1961). Due to their rapid growth rate and high nutrient uptake potential, cereals appear to respond more rapidly to resource enrichment than wild plant species (Fitter, 1994). Increased amount of available N generally favours the cereal crop relative to its common weeds (Jørnsgård *et al*., 1996; Nakoneshny & Friesen, 1961). Most weed seeds germinate randomly from the upper soil layer (0-3 cm), 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.

Spring wheat is known to be less competitive to weeds than barley and oat, but differences between varieties are not well known. In barley, major differences between varieties are observed (Christensen, 1995). In Swedish variety tests under organic farming conditions, differences among varieties of spring wheat were indicated (Larsson & Hagman, 1998).

### 4.4 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 breadmaking qualities.

Commercial grain samples from organically grown wheat varieties obtained during 1988-1992 showed a large variation in protein content between spring wheat and winter wheat (Starling, 1993). A significant higher percentage of the spring wheat samples achieved bread quality (protein %>10.5 %), but the variation among varieties was substantial. These results indicate that 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 produced a bread with a lower volume and a less elastic crumb (Haglund *et al.*, 1998). The bread volume can be increased by modifying the dough procedure or by addition of natural improving ingredients (Günther, 1993).

The producers of organic wheat flour claim that organic bread wheat, despite its lower protein and gluten content, produces 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 (Petrofsky & Hoseney, 1995; Janssen *et al.*, 1996). Studies on a range of biscuit wheat varieties showed, that rheological methods gave a better evaluation of differences in baking properties between varieties (Pedersen, 1999).

In the DARCOF programme 1 it was shown, that increasing the amounts of slurry and liquid manure increased grain yield and the protein and gluten content of grain and flour (Pedersen & Christensen, in prep.). A protein content of 10.5 % (dry matter) was achievable. However, the breadmaking quality of wheat in relation to N management and crop variety has not been evaluated thoroughly.

Rapid test methods have recently become available for qualitative and quantitative evaluations of cereals (Gerstenkorn, 1997; Wringley, 1999). 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. Fundamental rheological characteristics of gluten and wheat flour dough of a specific variety will be studied to evaluate the gluten structure as affected by organic and conventional growth conditions.

## 5. 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.

### 5.1 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.

### 5.2 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.

### 5.3 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.

### 5.4 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.

## 6. Description of workpackages including methods

**Table 1: Workpackage list**

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

**Table 2: Description of workpackages**

**WP1: Utilization of N in grazed grass/clover pastures**

| | |
|---|---|
| Workpackage number: | WP1 |
| Start date or starting event: | January 2001 |
| Responsible person: | Jørgen Eriksen, DIAS-CPSS |
| Contributing persons: | JE |
| Person-months: | 19.5 |

**Objectives**

This workpackage aims at improving the N utilization in organic dairy farming through investigating:

- nitrate leaching from older grazed pastures,
- the importance of pasture age for N accumulation and utilization in the succeeding crops, and
- the possibility for producing high quality spring wheat based on precrop effects of grazed pastures and organic fertilizer application without increasing the nitrate leaching losses.

**Description of work**

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:

**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 (unfertilized grass/clover and fertilized pure grass). In 2000 one half of each grassland history that was cultivated in 1997 is reseeded to grass, the other half being re-seeded in 2001. Thus, in the winter 2000-2001 leaching from cultivated land, $1^{st}$ and $7^{th}$ year pasture can be compared in associated plots, and in the winter 2001-2002 is it possible to compare $1^{st}$, $2^{nd}$ and $8^{th}$ year pasture allowing for estimates of the effect of increasing N accumulation in grassland on nitrate leaching.

**Activity 2: Ploughing grazed pastures with different age**
The plots in activity 1, where grassland histories of different age have been established, are used for determination of precrop effects. In 2002 are ploughed pastures 1, 2 and 8 years old. As a reference is used the associated cut grassland. Nitrate leaching is determined before and after ploughing the pastures, and in the following years using the suction cup technique as described above. The N up-take is determined in spring wheat after ploughing. The precrop effect from the combinations of pasture use and pasture age is determined from the yield of spring wheat compared to the yield of an adjacent area without grassland history, which is used as a nil precrop reference.

**Activity 3: Fertilizer strategy for production of high quality spring wheat after pastures**
The precrop effects determined in activity 2 may in some cases not be sufficient to produce spring wheat of breadmaking quality. Therefore different strategies for supplementary cattle slurry application is investigated. The slurry application strategies differ in quantity and time of application. For all combinations of precrop effect and supplementary slurry application is determined leaching losses in the following autumn and winter using ceramic suction cups and plant uptake. The quality for breadmaking purposes is evaluated in cooperation with WP4.

**Deliverables**
D13 Grain samples for breadmaking quality analysis
D21 Paper on nitrate leaching from pastures submitted
D26 Paper on N-utilization when ploughing pastures submitted
D27 Paper on good management practices when ploughing pastures submitted

**Milestones**
M1 The effect of pasture age on nitrate leaching has been analyzed and results submitted
M2 The efficiency of precrop effect for production of spring wheat of breadmaking quality has been determined and results submitted

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

| | |
|---|---|
| Workpackage number: | WP2 |
| Start date or starting event: | August 2000 |
| Responsible person: | Bent T. Christensen, DIAS-CPSS |
| Contributing persons: | IKT, EMH, BTC |
| Person-months: | 36 |

**Objectives**

The overall objective is to develop tillage strategies that improve the N economy of cereal production on soils with different organic matter management. More specifically, the work focuses on:

- tillage induced N mineralization and N uptake in wheat intended for human consumption
- interactions between organic matter management, preplant tillage intensity and the amount of organic N available for mineralization in the growth period
- the variations in N mineralization as affected by the intensity of tillage in the growth period
- mechanisms that control the retention of labile organic N in soil

**Description of work**

The experimental activity is based on ongoing field experiments.

**Activity 4: Organic matter levels and tillage frequency**

This activity is based on The Spring Cereal Rotation of the Systems Research Areas at Foulumgaard (Rasmussen & Hansen, 1994). 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. Before planting to spring wheat at double row spacing (25 cm), the plots are subjected to standard tillage operations. One third of each plot is left undisturbed during the active growth phase of the wheat. Half of the remaining plot is exposed to intensive physical disturbance by a PTO-driven row rotovator one time during the growing season, the other half is exposed to same soil disturbance two times. Effects of the soil disturbances are determined by changes in mineral soil N contents and in total-N in plant biomass one week after the soil disturbance. At harvest samples of grain and straw are analyzed for N content and wheat grains are submitted to WP4 for quality analyses.

**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 (Christensen *et al.*, 1994). In 1996, one of the four blocks at Lermarken ($B_4$-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 interactions between nutrient management and tillage are studied in spring wheat following a grass/clover crop ploughed under in the spring. Two tillage intensities are applied to each plot before ploughing. One half-plot is subject to ploughing and superficial seedbed preparation while the other half-plot is rotavated intensively before ploughing of the grass/clover sward. Effects of tillage are determined by changes in mineral soil N contents and in total-N in plant biomass at successive dates during the growth period. Grain and straw yields and N-offtakes are determined at maturity and grain samples from selected treatments are submitted to 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 but with winter wheat. Two tillage intensities are tested in winter wheat grown at double row spacing (25 cm) using implements that accomplish different intensity of soil disturbance (a conventional row crop cultivator and a PTO-driven row rotavator). A reference plot without soil disturbance is included. The effects of tillage intensity on N mineralization are determined by changes in mineral N contents in soil and total-N in plant biomass. At maturity, total crop N uptake is determined and grain samples are analysed for baking quality parameters (WP4). This activity includes two growth years.

**Activity 7: Mechanisms that control the retention and mineralization of labile organic N**
The impact of tillage on C and N turnover in soil will be studied in further detail in incubation studies. Intact soil cores are sampled immediately before soil tillage is carried out in the field experiments in Activity 6. Following addition of $^{15}N$-labelled ammonium, the effects of soil disturbance are followed by pool dilution techniques (Davidson *et al*., 1991, Murphy *et al*. 1999). The soil cores are subjected to controlled mechanical treatments (Hadas & Wolf, 1984) supplying energy levels comparable to tillage operations in the field. Disturbed and undisturbed reference samples are incubated at 20°C. Evolved $CO_2$ is collected continuously during two weeks. Inorganic $^{14}N$ and $^{15}N$ is determined after one and two weeks of incubation. Relationships between C and N turnover in disturbed and undisturbed soils are established. Net effects of soil disturbance on inorganic N levels in soil obtained in the incubation study are compared with the measurements of inorganic N in the field and by crop N uptake.

**Deliverables**

| | |
|---|---|
| D6 | Grain samples for breadmaking quality analysis |
| D10 | Grain samples for breadmaking quality analysis |
| D20 | Grain samples for breadmaking quality analysis |
| D22 | Paper on synchronizing N utilization by time and intensity of tillage |
| D25 | Paper on N turnover as affected by soil disturbance submitted |

**Milestones**

| | |
|---|---|
| M3 | Strategies for improving N-use efficiency in production of wheat of breadmaking quality have been investigated and results submitted |
| M4 | Studies of mechanisms that control the retention and mineralization of labile organic N have been carried out and results submitted |

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

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|---|---|
| Workpackage number: | WP3 |
| Start date or starting event: | August 2000 |
| Responsible person: | Jens Petersen, DIAS-CPSS |
| Contributing persons: | KR, JP |
| Person-months: | 26 |

**Objectives**

The main objective is to improve the crop uptake of N applied in animal slurry while reducing the N uptake by the weeds, and to improve the competitiveness of spring wheat towards weeds and resistance of the wheat to mechanical weed control.

More specifically the WP3 examines:

- the timecourse of $^{15}N$-nitrogen uptake in crop and weed as affected by placement geometry of banded animal slurry.
- the early root growth dynamics of crop cultivars and weed species in order to describe the competition potentials for nutrients.
- the influence of manure placement on competition between spring wheat varieties and weeds.

**Description of work**

**Activity 8: Recovery of $^{15}N$ in crop and weeds**

This activity is situated in the organic dairy crop rotation (FO1, see EXUNIT) at Foulumgård, Research Centre Foulum. Differences in soil fertility are obtained by selecting the two cereal growing fields on each side of the clover-grass for the experiment. A small amount of 99% $^{15}N$-ammoniumsulphate will be applied to animal slurry just before application. The slurry will be applied by hand in framed micro-plots (30×40 cm) placed beforehand in the field. A few days after slurry application straight and dense rows of spring wheat will be sown by hand-held equipment (Petersen, submitted). The main factor will be the distance (4, 10 and 16 cm) of the slurry band in relation to the crop row. The treatments will be established in several replicates for destructive sampling 4-6 times during the elongation phase of the crop. The last sampling will be performed just before ear emergence when maximum $^{15}N$-recovery occurs (e.g. Petersen, submitted). Samples of crop and weeds are handled separately, and analysed for $^{15}N$.

This activity follows an ongoing project concerning placement of animal slurry in organic spring cereals, with reference to improvement of crop competitiveness versus weeds. This project is a part of the Research programme to promote organic plant production based on natural defence mechanisms managed by DARCOF. The project ends in 2001, and the present workpackage starts in 2002. The ongoing project includes placement depth (5 or 15 cm) and degree of incorporation (banding or incorporated similar to harrowing). Only 2 sampling times are included: end of May (spring barley and weeds) and at ear emergence (barley only).

**Activity 9: Initial growth of roots**

Initial root growth experiments at semifield conditions with a range of spring wheat cultivars and weed species. Root growth will be measured approximately 1, 2 and 3 weeks after emergence/sowing to estimate initial growth rate. Single plants grown in plastic tubes will be washed and roots analysed by image analysis (WinRHIZO). Frequent measurements of spectral reflectance will be carried out in field trials.

**Activity 10: Competition between spring wheat and weeds**

Competition experiments in the seed crop rotation (FL2, EXUNIT) at Research Centre Flakkebjerg at the end of the rotation: Barley with undersown clover, white clover (seeds), winter oil seed rape and spring wheat. The experiment focuses on the effect of spring wheat varieties grown under increasing weed competition. The N source will be slurry injected before and after spring ploughing with green manure as reference treatment. Weed and crop density and biomass will be measured, and used to estimate interspecific and intraspecific competition. Weekly spectral reflectance measurements will be carried out during the growing season in weed free plots. Grain samples are delivered for laboratory analysis (WP4).

**Deliverables**

D3 Grain samples for breadmaking quality analysis
D7 Grain samples for breadmaking quality analysis
D11 Paper on initial root growth and competitive ability of cultivars as influenced by nutrient source and application method submitted
D12 Leaflet on weed control in high quality spring wheat
D17 Paper on $^{15}N$ uptake in crop and weeds as affected by placement submitted
D18 Leaflet on N uptake in crop and weeds as affected by placement submitted

**Milestones**

M5 The effects of placement geometry of $^{15}N$-recovery in spring wheat and weeds have been analyzed and results submitted
M6 Results on initial root growth and on crop/weed competition have been analyzed and submitted

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

| | |
|---|---|
| Workpackage number: | WP4 |
| Start date or starting event: | August 2000 |
| Responsible person: | Johannes Ravn Jørgensen, DIAS-PB |
| Contributing persons: | LP, JRJ |
| Person-months: | 44 |

**Objectives**

The overall objective of WP4 is to contribute to an improved production of high quality bread wheat from organic arable farms. More specifically, the objectives are to:

- analyse differences in baking quality and gluten content and structure among organically and conventionally grown wheat samples in order to establish suitable quality standards for organic bread wheat
- analyse and identify wheat varieties suitable for organic bread wheat production in Denmark
- adapt and implement rapid NIT based methods to test for breadmaking grain quality
- assist in clarifying how N management practices influence the bread wheat quality.

**Description of work**

The work in WP4 consists of field trails and laboratory analysis:

**Activity 11: Field trial Pajbjergfonden**

The Danish plant breeding company "Pajbjergfonden" supplies 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 are without animal manure, one is fertilised with pig-slurry and one is fertilised with cattle-slurry. The field trials will be repeated in year 2001 and 2002. The purpose of the project is to identify well-adapted high yielding wheat varieties for organic farming. Approximately

20 of these varieties are also tested in conventional field trials. Grain samples is delivered to laboratory analysis (Activity 13).

**Activity 12: Field trial Research Centre Flakkebjerg**
In the organic crop rotation area at Research Centre Flakkebjerg (FL1, EXUNIT) a field trial is established to examine the competition and synergetic relations between winter bread wheat and green manure. The field trial will be harvested in year 2000 and repeated in year 2001 and 2002. Grain samples is delivered to laboratory analysis at DIAS-PB and DIAS-FVFS.

**Activity 13: NIT and image analysis**
Grain analysis 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 will be attempted based on the flour analysis. Grain samples from Activity 11 and 12 and WP1-WP3 will be included.

**Activity 14: Flour analysis and baking characteristics**
Flour analysis focus on content of protein, gluten and starch. Furthermore flour yield and particle size distribution are determined. The elasticity and extensibility of the gluten structure and the ability of the starch to gelatinise are characterised by rheological measurements. Baking characteristics will be conducted on selected samples in collaboration with the milling company "Drabæks Mølle". Grain samples from Activity 12 and WP1-WP3 will be included.

**Deliverables**
D14 Paper on recommendations on choice of variety of organically grown winter wheat for breadmaking
D15 Paper on competition and synergetic relations between winter bread wheat and green manure
D23 Paper on suitable quality standards for organically produced bread wheat
D24 Paper on development of rapid non-destructive spectral quality analysis

**Milestones**
M7 Quality of organically grown winter wheat varieties analyzed and results submitted
M8 Competition and synergetic relations between winter bread wheat have been studied and results submitted
M9 Conclusions on studies of gluten structure and breadmaking properties. Results submitted

## 7. Implementation and time schedule

**Table 3: Deliverables list**

| Delive-rable no. | Deliverable title | Delivery date | Meeting | Nature |
|---|---|---|---|---|
| D1 | Time table, version 2 | Nov. 2000 | G1 | O |
| D2 | 1st status report | Nov. 2000 | G1 | Re |
| D3 | Grain samples for breadmaking quality analysis | Oct. 2001 | | O |
| D4 | Time table, version 3 | Nov. 2001 | G2 | O |
| D5 | 2nd annual status report | Nov. 2001 | G2 | Re |
| D6 | Grain samples for breadmaking quality analysis | Nov. 2001 | | O |
| D7 | Grain samples for breadmaking quality analysis | Oct. 2002 | | O |
| D8 | Time table, version 4 | Nov. 2002 | G3 | O |
| D9 | 3rd annual status report | Nov. 2002 | G3 | Re |
| D10 | Grain samples for breadmaking quality analysis | Nov. 2002 | | O |
| D11 | Paper on initial root growth and on competitive ability of cultivars as influenced by nutrient source and application method submitted | Nov. 2002 | | Pu |
| D12 | Leaflet on weed control in high quality spring wheat | Nov. 2002 | | Pup |
| D13 | Grain samples for breadmaking quality analysis | Dec. 2002 | | O |
| D14 | Paper on recommendations on choice of variety of organically grown winter wheat for bread making | Mar. 2003 | | Pup |
| D15 | Paper on competition and synergetic relations between winter bread wheat and green manure | Sep. 2003 | | Pu |
| D16 | Time table, version 5 | Nov. 2003 | G4 | O |
| D17 | Paper on $^{15}N$ uptake in crop and weeds as affected by placement submitted | Nov. 2003 | | Pu |
| D18 | Leaflet on N uptake in crop and weeds as affected by placement submitted | Nov. 2003 | | Pup |
| D19 | 4th status report | Nov. 2003 | G4 | Re |
| D20 | Grain samples for breadmaking quality analysis | Nov. 2003 | | O |
| D21 | Paper on nitrate leaching from pastures submitted | Dec. 2003 | | Pu |
| D22 | Paper on synchronizing N utilization by time and intensity of tillage | Jan. 2004 | | Pu |
| D23 | Paper on suitable quality standards for organically produced bread wheat | Jun. 2004 | | Pu |
| D24 | Paper on development of rapid non-destructive spectral quality analysis | Jun. 2004 | | Pu |
| D25 | Paper on N turnover as affected by soil disturbance submitted | Jul. 2004 | | Pu |
| D26 | Paper on N-utilization when ploughing pastures submitted | Oct. 2004 | | Pu |
| D27 | Paper on good management practices when ploughing pastures submitted | Oct. 2004 | | Pup |
| D28 | Final status report | Nov. 2004 | G5 | Re |

Project participants expect to contribute to DARCOF initiated workshops and to relevant international meetings and conferences.

**Table 4: Time table** (attached)

## 8. Collaborative partners

- In the DARCOF programme 1 simulation of N fluxes in grazed pastures using the DAISY model was initiated in collaboration with Assoc. Prof. Dr. L.S. Jensen, Plant Nutrition and Soil Fertility Laboratory, The Royal Veterinary and Agricultural University. This collaboration will continue in the present project.
- 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 (winRHIZO) will be analyzed in collaboration with “Pajbjergfonden” and Kai Lønne Nielsen (DIAS-Aarslev).
- The study on tillage effects on N turnover in soil will interact and draw upon the expertise in DARCOF II, Project I.7 ROMAPAC (project coordination Per Schjønning).
- 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.
- Erik Steen Jensen, The Royal Veterinary and Agricultural University (DARCOF II, project coordinator, Project I.5) has requested assistance with quality analysis of cereals used in their experiments.
- A project group with representatives from organic bread wheat farmers, the plant breeder “Pajbergfonden and the milling company “Drabæks Mølle” will be established.

## 9. Budget (1000 DKK)

Total for the project

| | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|
| WP1 | 0 | 219 | 230 | 716 | 281 |
| WP2 | 89 | 484 | 529 | 422 | 340 |
| WP3 | 120 | 192 | 609 | 185 | 0 |
| WP4 | 245 | 505 | 648 | 647 | 109 |
| Total – project I.4 | 454 | 1,400 | 2,016 | 1,970 | 730 |

WP1: Utilization of N in grazed grass/clover pastures

| Dept. CPSS | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|
| Salary (scientific) | 0 | 161 | 106 | 400 | 187 |
| Salary (technical) | 0 | 7 | 56 | 125 | 37 |
| Operation | 0 | 14 | 30 | 72 | 10 |
| Overhead | 0 | 37 | 38 | 119 | 47 |
| Total – WP1 | 0 | 219 | 230 | 716 | 281 |

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

| Dept. CPSS | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|
| Salary (scientific) | 45 | 166 | 217 | 183 | 192 |
| Salary (technical) | 0 | 77 | 82 | 59 | 62 |
| Operation | 29 | 161 | 142 | 110 | 29 |
| Overhead | 15 | 80 | 88 | 70 | 57 |
| Total – WP2 | 89 | 484 | 529 | 422 | 340 |

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

| Dept. CPSS | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|
| Salary (scientific) | 0 | 0 | 127 | 123 | 0 |
| Salary (technical) | 0 | 0 | 103 | 18 | 0 |
| Operation | 0 | 0 | 77 | 13 | 0 |
| Overhead | 0 | 0 | 61 | 31 | 0 |
| Total | 0 | 0 | 368 | 185 | 0 |
| Dept. CP | | | | | |
| Salary (scientific) | 35 | 70 | 105 | 0 | 0 |
| Salary (technical) | 20 | 60 | 61 | 0 | 0 |
| Operation | 45 | 30 | 35 | 0 | 0 |
| Overhead | 20 | 32 | 40 | 0 | 0 |
| Total | 120 | 192 | 241 | 0 | 0 |
| Total – WP3 | 120 | 192 | 609 | 185 | 0 |

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

| | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|
| Dept. PB | | | | | |
| Salary (scientific) | 35 | 53 | 123 | 140 | 35 |
| Salary (technical) | 38 | 100 | 87 | 87 | 0 |
| Operation | 12 | 53 | 82 | 53 | 0 |
| Overhead | 17 | 41 | 58 | 56 | 7 |
| Total | 102 | 247 | 350 | 336 | 42 |
| Dept. FVFS | | | | | |
| Salary (scientific) | 35 | 70 | 99 | 105 | 34 |
| Salary (technical) | 38 | 100 | 87 | 92 | 12 |
| Operation | 46 | 45 | 62 | 62 | 10 |
| Overhead | 24 | 43 | 50 | 52 | 11 |
| Total | 143 | 258 | 298 | 311 | 67 |
| Total – WP4 | 245 | 505 | 648 | 647 | 109 |

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**Appendix:** CVs of central persons are attached.

**2000**

| Activity | Month | 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 | | | | | | | | | | | | |
| 2 | Ploughing grazed pastures with different age | | | | | | | | | | | | |
| 3 | Fertilizer strategy for production of high quality spring wheat after pastures | | | | | | | | | | | | |
| M1 | The effect of pasture age on nitrate leaching has been analyzed and results submitted | | | | | | | | | | | | |
| M2 | The effiency of precrop effect for production of spring wheat of breadmaking 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 | | | | | | | | | | | | |
| 5 | Nutrient regime, preplant tillage and crop N uptake pattern | | | | | | | | x | x | x | x | x |
| 6 | N mineralization rate as affected by intensity of soil disturbance | | | | | | | | | | | | |
| 7 | Mechanisms that control the retention and mineralization of labile organic N | | | | | | | | | | | | |
| M3 | Strategies for improving N-use effiency in production of wheat of breadmaking quality have been investigated and results submitted | | | | | | | | | | | | |
| M4 | Studies of mechanisms that control the retention and mineralization of labile 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 | | | | | | | | | | | | |
| 9 | Initial growth of roots | | | | | | | | x | x | x | x | x |
| 10 | Competition between spring wheat and weeds | | | | | | | | | | | | |
| M5 | The effects of placement geometry on 15N-recovery in spring wheat and weeds have been analyzed and results submitted | | | | | | | | | | | | |
| M6 | Results on initial root growth and on crop/weed competition have been analyzed and submitted | | | | | | | | | | | | |
| | **WP4: Bread quality as affected by crop variety and N management** | | | | | | | | | | | | |
| 11 | Field trial Pajbjergfonden | | | | | | | | x | x | x | x | x |
| 12 | Field trial Research Centre Flakkebjerg | | | | | | | | x | x | x | x | x |
| 13 | NIT and image analysis | | | | | | | | | | | | |
| 14 | Flour analysis and baking characteristics | | | | | | | | | | | | |
| M7 | Quality of organically grown winter wheat varieties analysed and results sumbitted | | | | | | | | | | | | |
| M8 | Competition and synergetic relations between winter bread wheat and green manure have been studied and results submitted | | | | | | | | | | | | |
| M9 | Suitable quality standards for organically produced bread wheat have been established. Results submitted. | | | | | | | | | | | | |

**2001**

| Activity | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WP1 | | | | | | | | | | | | |
| 1 | x | x | x | x | x | x | x | x | x | x | x | x |
| 2 | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | |
| M1 | | | | | | | | | | | | |
| M2 | | | | | | | | | | | | |
| WP2 | | | | | | | | | | | | |
| 4 | | | x | x | x | x | x | x | x | x | x | |
| 5 | x | x | x | x | x | x | x | x | x | x | x | |
| 6 | | | | | | | | | | | | |
| 7 | | | | | x | x | x | x | x | | | |
| M3 | | | | | | | | | | | | |
| M4 | | | | | | | | | | | | |
| WP3 | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | |
| 9 | x | | | | | | | | | | | |
| 10 | | | x | x | x | x | x | x | x | x | x | x |
| M5 | | | | | | | | | | | | |
| M6 | | | | | | | | | | | | |
| WP4 | | | | | | | | | | | | |
| 11 | x | x | x | x | x | x | x | x | x | x | x | x |
| 12 | x | x | x | x | x | x | x | x | x | x | x | x |
| 13 | | | | | | | | | | x | x | x |
| 14 | | | | | | | | | | x | x | x |
| M7 | | | | | | | | | | | | |
| M8 | | | | | | | | | | | | |
| M9 | | | | | | | | | | | | |

**2002**

| Activity | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WP1 | | | | | | | | | | | | |
| 1 | x | x | x | x | x | x | | | | | | |
| 2 | | | | x | x | x | x | x | x | x | x | x |
| 3 | | | | x | x | x | x | x | x | x | x | x |
| M1 | | | | | | | | | | | | |
| M2 | | | | | | | | | | | | |
| WP2 | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | |
| 6 | | | x | x | x | x | x | x | x | x | x | |
| 7 | | | x | x | x | x | x | | | | | |
| M3 | | | | | | | | | | | | |
| M4 | | | | | | | | | | | | |
| WP3 | | | | | | | | | | | | |
| 8 | | | x | x | x | x | x | x | x | x | x | x |
| 9 | | | | | | | | | | | | |
| 10 | x | x | x | x | x | x | x | x | x | x | x | |
| M5 | | | | | | | | | | | | |
| M6 | | | | | | | | | | | M | |
| WP4 | | | | | | | | | | | | |
| 11 | x | x | x | x | x | x | x | x | x | | | |
| 12 | x | x | x | x | x | x | x | x | x | | | |
| 13 | x | x | x | | | | | | | x | x | x |
| 14 | x | x | x | | | | | | | x | x | x |
| M7 | | | | | | | | | | | | |
| M8 | | | | | | | | | | | | |
| M9 | | | | | | | | | | | | |

**2003**

| Activity | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WP1 | | | | | | | | | | | | |
| 1 | | | | | | | | | | | | |
| 2 | x | x | x | x | x | x | x | x | x | x | x | x |
| 3 | x | x | x | x | x | x | x | x | x | x | x | x |
| M1 | | | | | | | | | | | | M |
| M2 | | | | | | | | | | | | |
| WP2 | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | |
| 6 | | | x | x | x | x | x | x | x | x | x | |
| 7 | | | x | x | x | x | x | | | | | |
| M3 | | | | | | | | | | | | |
| M4 | | | | | | | | | | | | |
| WP3 | | | | | | | | | | | | |
| 8 | x | x | x | x | x | x | x | x | x | x | | |
| 9 | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | |
| M5 | | | | | | | | | | | M | |
| M6 | | | | | | | | | | | | |
| WP4 | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | |
| 13 | x | x | x | | | | | | | x | x | x |
| 14 | x | x | x | | | | | | | x | x | x |
| M7 | | | M | | | | | | | | | |
| M8 | | | | | | | | | M | | | |
| M9 | | | | | | | | | | | | |

**2004**

| Activity | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WP1 | | | | | | | | | | | | |
| 1 | | | | | | | | | | | | |
| 2 | x | x | x | x | x | x | x | x | x | | | |
| 3 | x | x | x | x | x | x | | | | | | |
| M1 | | | | | | | | | | | | |
| M2 | | | | | | | | | | M | | |
| WP2 | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | |
| M3 | M | | | | | | | | | | | |
| M4 | | | | | | M | | | | | | |
| WP3 | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | |
| M5 | | | | | | | | | | | | |
| M6 | | | | | | | | | | | | |
| WP4 | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | |
| 13 | x | x | x | | | | | | | | | |
| 14 | x | x | x | | | | | | | | | |
| M7 | | | | | | | | | | | | |
| M8 | | | | | | | | | | | | |
| M9 | | | | | | M | | | | | | |