Danish Research Centre for Organic Farming

Midterm Status Report 2002 and Application for Continuation in 2003

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The Directorate for Food, Fisheries and Agro Business
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1. Research program

Research in organic farming 2000-2005 (DARCOF II)

2. Project title and number

I.10 Development of organic vegetable cultivation methods, and the use of catch crops to improve the production and protect the environment

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6. Project period (month, year)

Start of project: 2000
End of project: 2004

7. Midterm description of the project, its results and progress, and application for continuation in 2003

A. Project summary

The development of organic vegetable production in Denmark is delayed by the fact that only a few species have been grown successfully in substantial amounts. To be able to fulfil the consumer demand for organic vegetables, all the major species must be produced in significant amounts. Such a diversification is now apparently taking place, and it is a major aim of the project to contribute to this. The major problems limiting the production of some of the main vegetables can be identified to be insufficient nutrient availability, difficulties with pest and disease management, and product quality. There is a lack of knowledge on cultivation methods adapted specifically for handling these problems in organic vegetable production. Several interactions exist between these problems and neither of them can be handled in isolation.

In this research project the major objective is therefore to create better opportunities for an increased organic production of a wider range of vegetables and other crops. The partial objectives address three important problem areas and their interaction and are to improve: i) nutrition of the crops, ii) handling of pests and diseases and iii) quality of the produce.

Development of cultivation techniques aimed at crop protection and quality and an improved basis for selecting well-adapted varieties will be very important for the development of organic vegetable production, and these subjects are addressed in the project. A major management option to handle a number of problems is to use catch crops and autumn green manures strategically in the crop rotation. The studies on catch crops involve a number of topics ranging from improving their effects on N leaching losses and on N supply for main crops, to beneficial effects on other major plant nutrients as K, S and P, and to aspects of soil biology relevant for crop protection.

Furthermore, catch crops may have other beneficial or undesirable effects on pests or diseases and these subjects are also addressed in the project. It is obvious that if other advantages, apart from improved N husbandry can be gained from the catch crops, this would encourage farmers to grow them more often. Therefore, improving the N effects, and improving the chances to use catch crops for other purposes at the same time can reduce leaching losses to the environment and improve the living conditions for soil organisms, which may serve as predators for pests.

The focus on catch crops and green manures may seem limited in a project on organic vegetable production, where animal manures often constitute an important part of the nutrient supply. However, we choose this focus for several reasons. Most of the vegetables are produced on plant production farms, where the access to farmyard manure and other manures will be limited. On such farms catch crops and green manures offer the possibility to utilise internal farm resources to improve the system. Lots of work has been done on the effects of farmyard manure during many years, and other DARCOF projects deal with this. We therefore believe that by focusing on the catch crops and green manures, we could contribute more new and innovative tools for management of plant nutrition and other aspects of organic production in sales crop rotations, and work with methods which hold the potential to improve the environmental as well as the agronomic aspects of the system at the same time.

Below is a list of the 9 work packages included in the project. After that, a short description of the activities planned within each of the work packages is included, which can be consulted when reading about the progress and results of the work packages under *C. Midterm results and progress* below.

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

Work-package No	Work package title	Responsible participant	Budget	Start	End
1	Nitrogen relationships of vegetable crops, and project co-ordination	Kristian Thorup-Kristensen	1.91	2000	2004
2	Entomopathogenic nematodes in organic cropping systems	Holger Philipsen	1.25	2000	2003
3	Varieties, growing stability, disease resistance and quality	Gitte Kjeldsen Bjørn	1.24	2000	2004
4	Catch crops as a tool for increasing P bioavailability on soils of low P status	Lars Stoumann Jensen	0.67	2001	2003

5	Influence of autumn green manure crops on club root (*Plasmodiophora brassicae*)	John Larsen	1.24	2002	2004
6	The effect of catch crops on soil mesofauna and earthworms	Jørgen Aagaard Axelsen	0.57	2000	2004
7	The effect of catch crops on N and K leaching and crop production, with focus on coarse sandy soils.	Margrethe Askegaard	1.62	2001	2004
8	Very deep-rooted crops and catch crops in the crop rotation, N dynamics and modelling	Kristian Thorup-Kristensen	1.82	2000	2004
9	The effect of catch crops on sulphate leaching and availability of S for the succeeding crop	Jørgen Eriksen	0.95	2001	2002

Objectives and work description for each work package

WP1: Nitrogen relationships of vegetable crops, and project co-ordination.

Objectives

1) To co-ordinate the VEGCATCH project.
2) To acquire information about rooting depth during growth, soil N depletion, N uptake dynamics, N residues left in the soil, and the amount and quality of crop residues by a number of vegetable crops. For some vegetable crops where this is relevant, rooting depth and soil depletion below 1.0 m will be studied.
3) To supply data on N root growth and N dynamics for model simulations (Project BIOMOD) and for development of the decision support system on the use of catch crops (WP8).
4) To test the value of green manure crops incorporated in the late spring, as an N source and alternative to full year green manure for N demanding vegetable crops.

Description of work

Coordination of the project includes the production of status reports etc.. Further, it includes securing that general information about the project is communicated. This will be done through articles about the project and arranging a workshop for farmers, advisors, and others. A yearly workshop, where the participants of the project will meet and exchange results and ideas will also be arranged. Finally, the coordination includes follow up on the single work packages.

Crops of Chinese cabbage, celery, red beets, sweet corn, iceberg lettuce and leek will be grown and their root growth will be studied with a minirhizotron system. Samples will be taken during the growing period to determine biomass production, leaf area and N uptake and related to root growth (depth and distribution). At harvest yield, N uptake, N in crop residues and amount and depth distribution of N residues in the soil will be measured. The vegetable crops will be grown after autumn and spring incorporated green manure crops, to study the interactions between rooting depth and N demand and variable soil N profiles. Three of the crops will be studied during the years 2000 and 2001, and the other three will be studied during 2002 and 2003.

For carrot and white cabbage root growth and soil depletion will be followed to at least 2.0 m depth, this study will be combined with catch crop studies (see WP8). These vegetable crops will be grown in 2001 and 2002.

Two legumes will be established as undersown crops in spring cereals, and left to grow in the autumn, and then incorporated either in March before growth resumes in the spring, in early May or in late May. Biomass production, N content and C/N ratio in the legume material will be measured in November and at the time of incorporation. White cabbage will be established in early June, and growth, yield and N uptake measured, and compared to plots without preceding legumes. N_{min} will be measured in the late summer in subplots where no cabbages were grown. The legumes will be established by undersowing in spring cereals in the spring of 2000 and again in 2001, and their effect on N supply for vegetable crops will thus be measured in 2001 and in 2002.

WP2: Entomopathogenic nematodes in organinic cropping systems

Objectives

1) To study differences between cropping systems - especially systems including catch crops - and the ability of the different systems to support growth or maintenance of entomopathogenic nematodes.
2) To study whether specific crops (especially cabbage and carrots) can benefit from entomopathogenic nematodes occurring in the above mentioned systems

Description of work

1) Interactions of entomopathogenic nematodes, pest insects and plants in the organic cropping system at Årslev.

In each of the six fields in the Årslev system, plots of 4-9 square meters will be marked and monitored for naturally occurring entomopathogenic nematodes in April 2000. Depending on the results, a proportion of the test plots will be inoculated with entomopathogenic nematodes of one or more species to ensure measurable amounts of nematodes in the given plot. The test plots will be selected to enable studies on the impact of main crops and catch crops on entomopathogenic nematode population dynamics. The number of entomopathogenic nematodes in each of the test plots will be quantified in April/May, July/August and October/November in each year by baiting soil samples with *Galleria mellonella* and *Tenebrio molitor* followed by dissection to reveal the numbers of entering nematodes. Each year at the end of each growing season, crop production and the number of pest insects at the plants in the carrot and cabbage fields will be estimated. In addition the occurrence of indifferent or beneficial insect species will be quantified in test areas with high and low success in nematode establishment.

2) Comparing levels of entomopathogenic nematodes on neighbouring farms with different cropping systems.

Neighbouring farms will be selected that are identical in regard to as many parameters as possible but with different growing systems. Selected farms with short and long organic farming history will be compared to their neighbouring farms in relation to nematode prevalence. The main focus will be put on organic growers including vegetables in their rotation system. Up to 10 pairs of farms will be studied by taking soil samples. Each of the samples will be baited and nematodes will be quantified and identified and correlated to cropping system, soil type and number of years with organic farming.

3) Screening of plant species for their value of supporting populations of entomopathogenic nematodes.

At KVL experimental farm Snubbekorsgård different plant species (mainly selected catch crop species from WP8) will be screened for their ability to preserve populations of entomopathogenic nematodes. The plants will be chosen among plants being regarded as valuable catch crops in the rotation system. Soil samples will be taken and nematode numbers quantified as described above (part 1).

4) Susceptibility of beneficial arthropods to entomopathogenic nematodes.

Through out the years beneficial arthropods will be collected and their susceptibility to entomopathogenic nematodes will be tested in the laboratory. As a minimum 10 species will be tested each year.

WP3: Varieties, growing stability, disease resistance, and quality

Objectives

1) To help the organic growers to choose the most stable and well-adapted varieties in crops like cauliflower, carrots and onions, and to make guidelines for choosing varieties with optimal characteristics for organic growing.
2) To study the significance of various pests, diseases and quality defects in vegetables grown in organic or conventional production systems, and if possible to identify pests or disease which are less severe in organic than in conventional vegetable production for future studies of natural regulation of pest organisms.

Description of work

Varieties of the most important vegetable crops (e.g. Carrot, cauliflower and onion) will be tested in the organic rotation in Årslev, parallel to the conventional variety trials normally performed in Årslev.

Varieties of the three crops will be tested each year from 2000 to 2004 to get reliable information of differences or similarities in the two growing systems. We plan to include varieties of more vegetable species (e.g. broccoli and

Chinese cabbage) in the tests, but not all five years; the final choice of species will depend on which ones are to be tested conventionally anyhow.

From emergence to harvest a number of parameters will be registered: Leaf top size (relevant for weed competition), growth duration, harvest spread, yield, product quality, damages by diseases (e.g. Downy mildew, Cavity spot, scab and Alternaria) and pests (e.g. cabbage root fly, carrot fly, aphids, caterpillars and cutworm). After harvest carrots and onions will be placed in cold-storage to register the susceptibility to storage disorders (e.g. watery soft rot, crater rot, neck rot and liquorice rot). Samples will be taken in the two growing systems to quantify the amount of entomopathogenic nematodes (WP2) that may be one reason for possible differences in damage by important pests.

WP4: Catch crops as a tool for increasing P bioavailability on soils of low P status

Objectives

1) To test selected catch crop species for their P uptake capacity on a low P status soil.
2) To quantify the influence of these catch crops on subsequent main crop yield and P uptake
3) To quantify possible interactions between catch crop species, the crop rotation (with or without grass-clover ley) and additional P supply for the main crop.

Description of work

Studies will be carried out in a field experiment over two years. Catch crop species will include a fallowed control, ryegrass and 3-5 selected species. This selection will be closely co-ordinated with the catch crop experiments at Årslev and may draw on results of the wide screening of potential catch crops carried out by Rydberg (1998). Species known to have special abilities for P acquisition (e.g. lupin, buckwheat) will be considered.

Experimental plots will be located at the Agricultural University Experimental Farm, Taastrup, in the *Long-term nutrient depletion trial*, an 8.5 ha sandy loam field, which has been cultivated continuously with spring barley and N, but no P and K fertilizer for more than 30 years (1964-1996), producing relatively low P and K test values (approx. 10 mg bicarbonate-P and 50 mg extractable-K pr. kg soil). In 1996 a new field trial was laid out in approximately ¾ of the field and two crop rotations were started, each with seven nutrient treatments and two replicates (block design). Each major plot is approx. 1250 m^2. In the remaining part of the field, the continuous spring barley cropping has been carried on with N, but no P and K fertilizer.

Plots will be placed in one of the rotations where the last preceding crop was a second year grass-clover ley, and the plot will subsequently be sown to spring wheat or barley, in which the selected catch crops will be undersown.

The catch crops will be placed in three treatments, differing in P availability and whether grass-clover ley preceded the spring wheat: i) treatment ***B*** (moderate NKS, but no P fertilisation, grass-clover ley preceding year), ii) treatment ***D*** (moderate NPKS fertilisation, grass-clover ley preceding year) and iii) ***Outside*** (adequate N, but no P and K fertilisation, continuous cereal cropping). The treatments will be carried out in 3 replicated, randomised minor plots within one of the major plots. In the following year, the catch crops will be undersown in spring barley in the other major plot replicate, to avoid confounding.

Sampling and analyses will include i) biomass production and C, N and P content of the catch crops in late autumn and early spring, ii) soil bicarbonate P_i and P_o in early spring and iii) main crop biomass production and P content two or three times in the initial growth stages and once at harvest.

WP5: Influence of autumn green manure crops on club root (*Plasmodiophora brassicae*)

Objectives

1) ***To identify crucifer species or genotypes with full or partial resistance to* Plasmodiophora brassicae**
2) ***To identify crucifer catch crops that can be grown without increasing subsequent disease pressure of* P. brassicae *or can actually reduce subsequent disease pressure.***

Description of work

Resistance of different Brassica species to P. brassicae

A wide range of cruciferous crops, including exotic *Brassica* species suitable as a green manure crop are tested for susceptibility to *P. brassicae* under controlled growth condition using natural homogenized infested soil. Direct estimation of resting spores in the soil will be performed using the method described by Botz *et al.* (1988).

Brassica species with high tolerance to *P. brassicae* or and reducing effect on the number of resting spores are selected for test in field experiment.

Test of different Brassica and perennial green manure crops on disease pressure of P. brassicae

In field-experiments, the influence of a number of crucifer and perennial green manure crops on the survival of *P. brassicae* will be investigated. A bioassay method (Wallenhammar, 1996) using susceptible bait plants is used to estimate the infection capacity of *P. brassicae* in autumn before sowing the green manure crop and then again next spring before planting the cash crop e.g. red cabbage. The effect of the different green manure crops on the red cabbage is evaluated by measuring the infection level by scoring for club root symptoms and yield (quantity and quality) in the following growth season.

WP6: The effect of catch crops on soil mesofauna and earthworms

Objectives

1) To describe the effect of growing catch crops on the populations of a number of soil living animals, and to test whether important differences exist among catch crops in their effect on the soil fauna.
2) To obtain data on the effect of catch crops on the soil fauna which can be used for modelling purposes in the BIOMOD project.

Description of work

The effect of catch crops at different levels of nitrogen and potassium on the soil fauna.

The soil fauna will be sampled in the fields used by WP7. Sampling will take place regularly over the entire cropping season in order to get information on the population development during the growth phases of both the catch crop (autumn) and the following main crop (spring and summer). The data will be analysed in relation to the catch crop species, chemical measurements from WP7 and crop yield.

The effect of deep-rooted catch crops on the soil fauna.

The soil fauna sampling will take place in the fields used by WP8. Sampling will start in autumn and continue until the following summer. Results will be analysed in relation to catch crop species and the data measured in WP8

The effect of undersown catch crops in cereals on the soil fauna

Sampling will start already in the cereal where the undersown catch crop is being established and continue until the harvest of the following main crop. Results will be analysed in relation to catch crop species and the data measured in WP8

The results will be used to validate the food web model in the project “Interactions between nitrogen dynamics, crop production and biodiversity in organic crop rotations analysed by dynamic simulation models”, if both project come through.

Sampling

Microarthropods will be sampled with a 5 cm diameter core sampler and extracted in the laboratory by a high gradient extractor. Earthworms will be washed out from 25×25×25 cm soil samples taken with a spade. Collembola and earthworm will be identified to the species level and mites to the group level.

WP7: The effect of catch crops on N and K leaching and crop production, with focus on coarse sandy soils.

Objectives

1) To test whether catch crops can significantly reduce K leaching losses on a coarse sandy soil, and whether legume catch crops will reduce K leaching more than non-legumes, as their growth is not N limited.
2) To test whether undersown legume catch crops can supply enough N to sustain continuos grain production on a coarse sandy soil.
3) To identify legume- and non-legume catch crop species suitable for undersowing on coarse sandy soil.

Description of work

The investigation is carried out on two locations: on a coarse sandy soil low in exchangeable K at Jyndevad experimental station and on a sandy loam at the organic vegetable workshop area at Research Centre Årslev.

Jyndevad:

Field experiment 1: An experiment with three catch crop treatments: Clover, ryegrass and no catch crop will be established. These treatments are tested under two N-levels (i.e. undersown in barley or lupine) combined with two levels of K availability originating from K fertilisation at the start of the experiment. Dry matter yields and nutrient content in the catch crop, are measured. The following spring a cereal crop will be established and the yield measured. Soil analysis of mineral nitrogen, the different K fractions and other relevant soil parameters are carried out. This experiment is carried out in collaboration with a research project focusing on protein crops (see collaborative partners).

Field experiment 2: Two types of persistent catch crops, a non-N_2-fixing and N_2-fixing, are established each year in a four year continuos spring cereal rotation. Dry matter yields in the catch crops, grain yield, nitrate and potassium leaching, N_2-fixation among other essential plant and soil parameters are measured.

Field experiment 3: A number of different non-N_2-fixing and N_2-fixing catch crops and their mixtures are undersown in a spring cereal. Dry matter yield and nutrient content of the catch crop and grain yields of the cover crop and the succeeding spring cereal are measured among other essential plant and soil parameters.

Yield and leaching results from the treatments with and without catch crops in an ongoing project at Jyndevad "Crop rotations for cereal production in organic farming" (see collaborative partners) will be used in the data analysis in order to relate the results to a crop rotation level.

WP8: Effects of very deep-rooted crops and catch crops on N dynamics and modelling

Objectives

1) To test the significance of including crops and catch crops with very deep rooting into cropping sequences on the N dynamics in the soil, especially the effects on N dynamics in soil layers below 1.0 m (to 2.0 m or to 2.5 m if possible). Special emphasis will be given to the significance of differences in root growth among species which all have effective rooting depths of 1.0 m or more.
2) To obtain data on root growth and soil N dynamics which can be used to validate model simulations of deep soil N dynamics.
3) To identify plant species with very deep rooting which can be established as undersown catch crops in cereals.
4) To utilise current knowledge and results obtained through objectives 1)-3), and simulation modelling to build a decision support system for optimal catch crop strategies.

Description of work

An experiment at Årslev with three year long cropping sequences including species with very different rooting depth will be made to study the effect of very deep rooting on N dynamics especially in the subsoil. The experiment will start with catch crops in the autumn at a high leaching position in the crop rotation, where plots will be grown with Italian ryegrass, fodder radish or no catch crop. In the following year leek, carrot and white cabbage will be grown, and in the third year barley will be grown with either no catch crop, or catch crops of ryegrass or chicory (or another species which has been found to have very deep rooting, see Objective 3). We will not grow all 27 possible combinations, but 10 selected to allow us to make the most relevant comparisons. The experiment will be repeated twice (one series started in the autumn of

2000 and the next in the autumn of 2001) and have two replicates each year.

In the experiment, rooting depth of the crops will be measured with the minirhizotron system, where minirhizotrons extending to a depth of approx. 2.2 m will be used. Soil sampling to a depth of 2.5 m will be made in the late autumn and again in the spring and the content of nitrate-N determined, with a final sampling in the spring of year 4 to estimate the effect of the undersown catch crops. Some of the soil samples will be analysed for sulphate as well (see WP9) or soil water will be extracted and analysed for content of important ions (see WP7).

An experiment will be made to identify very deep-rooted plant species, which can be grown as undersown catch crops in spring barley. Chicory and other relevant dicot species (including some interesting legume species) with potentially deep rooting will be grown as undersown catch crops in barley, and compared to plots with perennial ryegrass and control plots. The experiment will be made on a field where significant amounts of available N will be present in the subsoil. In November soil samples will be taken to 2.0 or 2.5 m. Root growth will be tested with 2.2 m deep minirhizotrons on the species which are found to be most interesting; in the first year at least on ryegrass and chicory. N uptake and C/N ratio of the catch crops will be determined in the late autumn, and N_{min} will be measured in the following spring to test whether the catch crops can supply N for a succeeding crop as well as reduce leaching losses. We want to test approx. 20 crops, but do not have the capacity to test that many at once, thus the experiment will start in 2000 and be repeated four times, but only the two control treatments (no catch crop and ryegrass) will be included every year. Some of the species will be studied for their effect on S leaching and subsequent S mineralization (see WP9), whilst other of the species will be studied for their ability to mobilise soil P (see WP4) as well.

Development of a decision support system will be initiated with a synthesis of existing knowledge about the effects of catch crops on crop rotation N dynamics, as it can currently be described by the dynamic simulation model DAISY (Jensen *et al.*, 1999). This will involve close co-operation with the modelling project (BIOMOD), but in addition more detailed calibration of crop modules for various vegetable crops will have to be performed as well as preliminary calibration of deep root development. All the scenarios described for the experimental activities of this WP will then be simulated and the response matrix for the different strategies used as a basis for drafting the structure of decision support system. Once experimental data from this WP and the scenario analyses of the modelling project (BIOMOD) are available in the later stages of this project, further validation and refinement of the decision support system can be carried out.

WP9: The effect of catch crops on sulphate leaching and availability of S for the succeeding crop

Objectives

1) To determine the ability of catch crops to reduce soil sulphate concentrations during autumn and winter
2) To determine the ability of catch crops to make S available for the succeeding crop through mineralization.

Description of work

At the workshop area in Årslev a number of different catch crops and catch crop strategies are tested (see WP8). With emphasis on the cruciferous species, these experiments are used as the basis for studying the effect of catch crops on sulphate leaching and availability of S in the succeeding crop in combination with pot experiments. The investigation is focussing on two aspects:

1 The ability of catch crops to reduce soil sulphate concentrations during autumn and winter

The soil sulphate content is determined in the soil profile under catch crops during autumn and winter by soil sampling in 25 cm intervals in 0-150 cm. Concurrently, plant material is sampled to determine the S-uptake in catch crops. The plots will be Italian ryegrass, fodder radish or no catch crop. Additionally Chicory and other dicot species will be used (see WP8).

2 Mineralization of catch crop S

The mineralization of S in catch crops is investigated by soil sampling in the field. To estimate the straight effect of S, catch crops are furthermore incorporated in pot experiments under natural temperature conditions (Eriksen *et al.*, 1995) where other main nutrients are available. In pots without plant cover the timing of the S release is followed by soil water sampling and in pots with plant cover its relation to plant needs is determined. Factors capable of improving this synchrony (incorporation time, method and crop species) are investigated. As test plant spring barley is used from which harvest yields will show differences in S availability.

B. Objectives and expected achievements

The major research objectives of this project are to create better opportunities for an increased organic production of a wider range of vegetables and other crops.

As shown in figure 1, we want to work with some of the main problems limiting current organic vegetable production, i.e. pests and diseases, nutrient limitations and the interactions between them. The partial research objectives have therefore been formulated to address these important problems and their interaction as outlined in figure 1:

Improve nutrition of the main crops through strategic and integrated use of catch crops and green manures and study both their direct effects on nutrient retention and mobilisation as well as indirect effects through impact on soil fauna.

Handle pests and diseases through improved cultivation strategies, including the effects of catch crops and green manures on pathogen pressure and natural fauna of predators of pest insects.

Improve the quality of the produce, through adapted cultivation methods, variety choices and interactions with both diseases/pest and nutrition status

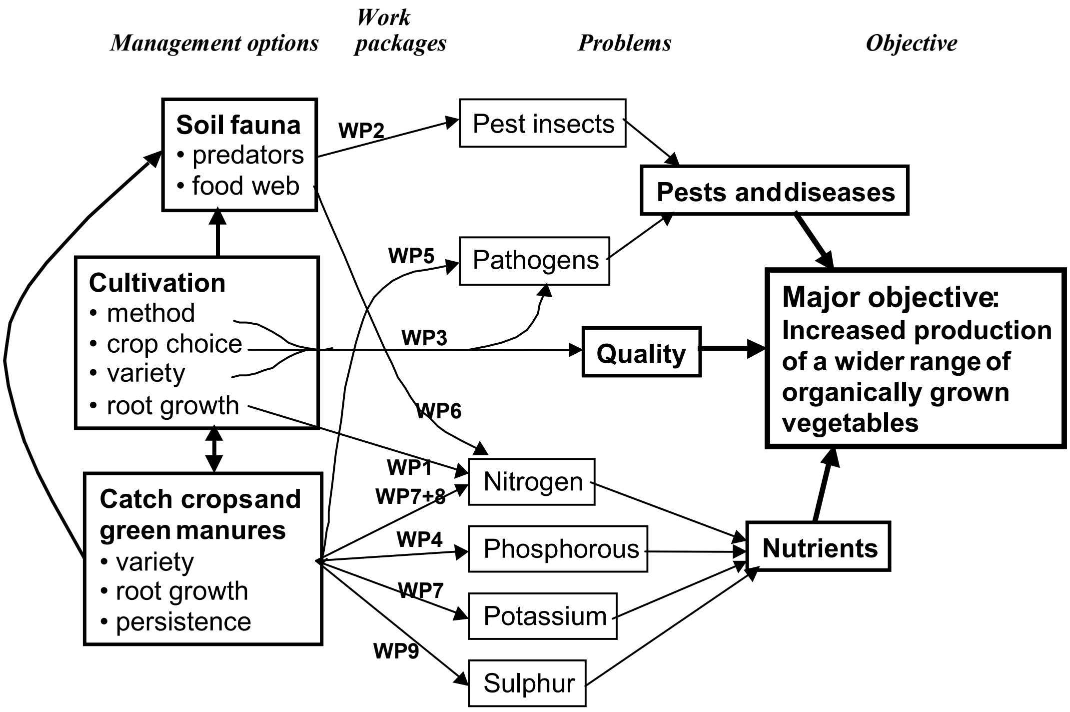


Figure 1. Overview of the major problems, management options and their interaction in relation to an increased production of organic vegetables. The figure is not a representation of all interactions, only the most important ones addressed in this project have been included. WP refers to the work packages described in section 4 and 6.

To pursue the objectives a number of work packages have been designed. With these work packages we have aimed at tackling some, but not all, of the important problems identified in figure 1.

With the results from this project, a major achievement will be the improved recommendations to farmers, advisors, and agricultural students. We expect the project to have a large impact on actual production practices, as the major part of the research will be conducted in a functioning and well-known vegetable crop rotation experiment (Thorup-Kristensen, 1999). The dissemination of results naturally includes communication of already existing knowledge, most directly through the development of a decision support system. New and already existing knowledge will also be communicated through the project home page, through articles and lectures for farmers and advisors and through education of students at the Royal Veterinary and Agricultural University. We plan to attach a number of agricultural students to the project for doing their MSc projects.

Apart from fulfilling the defined objectives of the project, the results could be valuable in other contexts as well. If catch crops become more widespread in organic crop production, we believe that we have not only contributed to an increase in organic production, but also done so in a way that is very well in line with the basic ideas behind organic farming. Growing catch crops is a biological method to handle problems, and by growing a number of different plant species as catch crops we use the internal resources on the farms, and introduce a higher biological diversity. Further, catch crops can be expected to favour soil organisms and other species in the agricultural areas, and to contribute to maintain or build up soil organic matter.

Some of the results could also be very valuable to conventional farming. With increased environmental concern, and regulations on the use of pesticides and N fertilizers, alternative methods for crop protection, selection of more tolerant varieties and better understanding of how to design N efficient crop rotations could be used directly in conventional farming. New legislation (since 1998) aimed at reducing N losses from agriculture requires Danish farmers to grow catch crops on part of their area. Results from this project, which make catch crops more useful for reducing N losses, increasing N supply for main crops and achieving other goals could be valuable both for farmers directly, and for future adjustments of the legislation.

Most scientific attempts to quantify N leaching losses are based on the assumption that the effective rooting depth is approximately 1.0 m. This assumption is used both when collecting soil water to study the leaching experimentally, or when using simulation models to estimate N leaching in various scenarios. If some crops or catch crops have effective rooting depths, which are significantly deeper than 1.0 m, conclusions based on this assumption could be misleading, not only quantitatively, but also give wrong conclusions when comparing the effect of various crops or other scenarios. The results from this project could help evaluate the validity of the hypothesis that 1.0 m can reasonably be assumed to be the bottom of the rooting zone, or whether other approaches must be used to arrive at the right conclusions.

C. Midterm results and progress

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

The VegCatch project is now more than half way through the project period. The work packages are not all running for the whole period, e.g. WP5 did not start until the beginning of 2002, whereas WP9 will end by the end of year 2002. Therefore the different work packages are at quite different stages as it will be evident from the presentation of each of them below.

Interesting results have been produced, but there are few “final” results as yet. A main idea behind the project was to study the effect of crops (main crops, nitrogen catch crops or green manures) on succeeding crops in a rotation. Many of the single experiments run for a rather long time, as “pre-crops” must be established, before the measurements of pre-crop effects can be made. In a few of the experiments the same plots are followed for three years to study such effects during longer cropping sequences. Therefore, most of the results presented in this report are preliminary.

In studying the pre-crop effects of main crops, the studies must concentrate on the crop species, which are normally grown, as these crops are chosen by farmers based on the marked and the economic results to be expected. When growing catch crops and green manures on the other hand, we have found it obvious also to study species, which have not normally been grown. Catch crops and green manures are grown for their effects on the soil, and the choice of plant species are not limited by factors such as marketability.

In some of the experiments very significant effects of catch crops have been observed, with striking differences among the different catch crop/green manure species. This is the case with the effect of catch crops on the population density and species composition of mesofauna and earthworms in the soil, on rooting depth of the catch crops, and on their sulphur uptake from the soil, C/S ratio and S release for the succeeding crop. We expect further interesting results to be found in the experiments on catch crop effects on P dynamics, on N and K dynamics and losses on sandy soil, on the occurrence of *Plasmodiophora brassicae* (club root) and on spring growing green manures, where few results have been obtained yet.

The results of WP2 indicate that catch crops may have a limited effect on the occurrence of entomopathogenic nematodes (EPN) in the soil, but there seem to be clear effects of the choice of main crops. Interestingly, a full year green manure crop did actually reduce the occurrence of EPN in the soil, whereas rapeseed, carrots, cabbage and peas increased it. Highly significant effects of different main crops in a cropping sequence has also been found in WP8 where the potential benefit of introducing very deep rooted crops such as cabbage at the right place of a crop sequence has been shown. Studies of root growth and N dynamics of a number of vegetable crops in WP1 will make these results more useful for vegetable crop rotations.

In some of the work packages more general "system effects" have also been found. Studies of EPN in the soil of an organic farm and at two neighbour farms showed very large differences. Also the study of different varieties of cauliflower, onion and carrot grown both organically and in conventional farming show system differences. Some diseases and pests are less problematic in the organic production than in conventional production. With one of the crops (carrots) this has actually led to higher saleable yield in organic production, especially due to a lower incidence of the cavity spot disease.

Many of the participants in the projects have been working on organic farming research for a number of years before the project, e.g. on previous DARCOF projects. This helps the dissemination of the results, already at this stage of the project where we have relatively few results. The ideas of the project and the results obtained within the VegCatch project are thereby included together with results from previous work in presentations and publications aimed at farmers, advisors and agricultural students.

Based on the progress, and the results until now, we believe that the project will be able to reach its main goals, and to produce a number of results which is interesting both scientifically and for practical use in organic farming.

WP1 Nitrogen relationships of vegetable crops

1.1. Experiments with root growth of six vegetable crops

The first round of experiment including red beet, celeriac and sweet corn was finished last year. In 2000, the sweet corn crop failed, but apart from this, the experiment has been successful. Red beet reached rooting depths of between 150 and 200 cm, whereas celeriac reached less than 50 cm. In 2001 sweet corn grew to between 90 and 120 cm. The crops do not distribute their roots equally well in the soil. At a similar average rooting density, red beets had roots in 85% of the counting grids, whereas celeriac had roots only in 55%. Celeriac often showed very high root densities in single grid fields, with 2 to 6 root intersections per cm grid line, whereas the highest density observed on red beet was c. 1.5 intersections per cm grid line. This indicates a more optimal root distribution of red beet than of celeriac, also within soil volumes well rooted by both crops.

In 2001 there were a clear effect of incorporation time of the preceding green manure crop on rooting depth of the vegetable crops. Rooting of sweet corn and red beet was approx. 50 cm deeper after autumn incorporation of the green manure than after spring incorporation (figure 1.1). A similar effect was only indicated in the results of 2000.

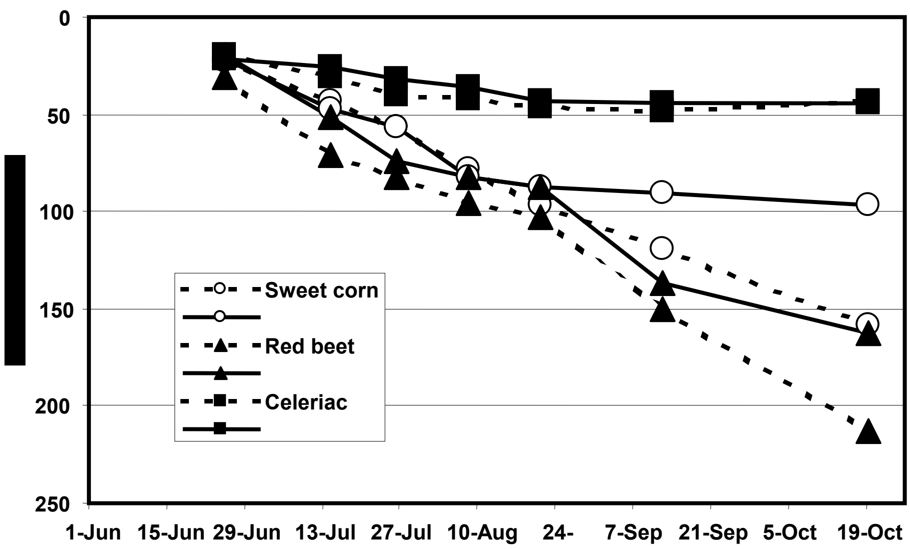


Figure 1.1. Rooting depth development of three vegetable species during 2001. Dashed lines show development were the preceeding catch crop was incorporated in November, full lines where it was in corporated in April.

N_{min} measurements showed a clear relationship between the observed rooting depth, and the ability of the crops to deplete N_{min} from the different soil layers during the growing period. Red beet depleted the upper 150 cm of the soil to only approx. 20 kg N_{min} ha^{-1}, whereas celeriac left approx. 75 kg N ha^{-1}, and the N uptake of the crops corresponded to the difference in soil depletion. Results obtained in WP8 show a very clear example of why this sort of information is important for design of crop rotations with a high N use efficiency and low N losses to the environment.

In 2002 and 2003 the experiment is continued with three other vegetable crops, potatoes, Chinese cabbage, and squash. The very preliminary results show potatoes to have rooting depths of roughly 70 cm, Chinese cabbage showed fast root growth, but with a short growing season only medium rooting depth of less than 150 cm, whereas squash which are still growing in early September show rooting depths of more than 200 cm, combined with very high root intensities.

A masters thesis (*Root systems of vegetables and root development in relation to nitrogen distribution in the soil profile*) have been made and defended in 2002 as part of this study. Currently two students are working on their bachelor thesis focussing on other aspects of the study.

1.2. Experiments with spring green manure

The 2001 version of this experiment mostly failed. One of the two green manures (black medic) did not survive the winter, and a mistake occurred in the incorporation of the green manure. Only a few results from this experiment can be used, i.e. the effect of white clover on the first two incorporation dates. This year the experiment has gone well, but no data are present, as the cabbage crop is still growing in the field. Visual evaluation show clear effects of the treatments, apparently especially of late incorporated white clover.

WP2 Entomopathogenic nematodes in organic cropping systems

2.1. Interactions of entomopathogenic nematodes (EPN), pest insects and plants in the growing system at Årslev

In 2001 the occurrence of EPN was estimated in spring and autumn in four fields at Årslev. In addition, host specific and soil living plant pests were quantified (Figure 2.1). In all fields EPN (*Steinernema feltiae*) had been inoculated to half of the plots to ensure a measurable number of nematodes and to study the survival of the nematodes. The plots without nematode inoculation were surveyed again in spring 2002 and in October 2002 all plots will be surveyed and the soil living pest insects has been / will be quantified. Further, nematodes were quantified in the root zone of cabbage and carrot plants and related to the presence of cabbage root flies and carrot flies at the same plants (data not ready). These observations were also repeated in 2002 where additional observations were made in pea (see Task 3) because of the high infection with *Sitona lineatus.*

In general, the occurrence of EPN at Årslev is at a low level and a measurable effect on pest insects has not been documented. However, the nematodes were over-represented in plant samples, which indicated interactions between nematodes and plant pest. In 2002 nematode infected *Sinota lineatus* larvae were observed in the pea field. It has also been demonstrated that nematodes can be established and survive for ½-1 year.

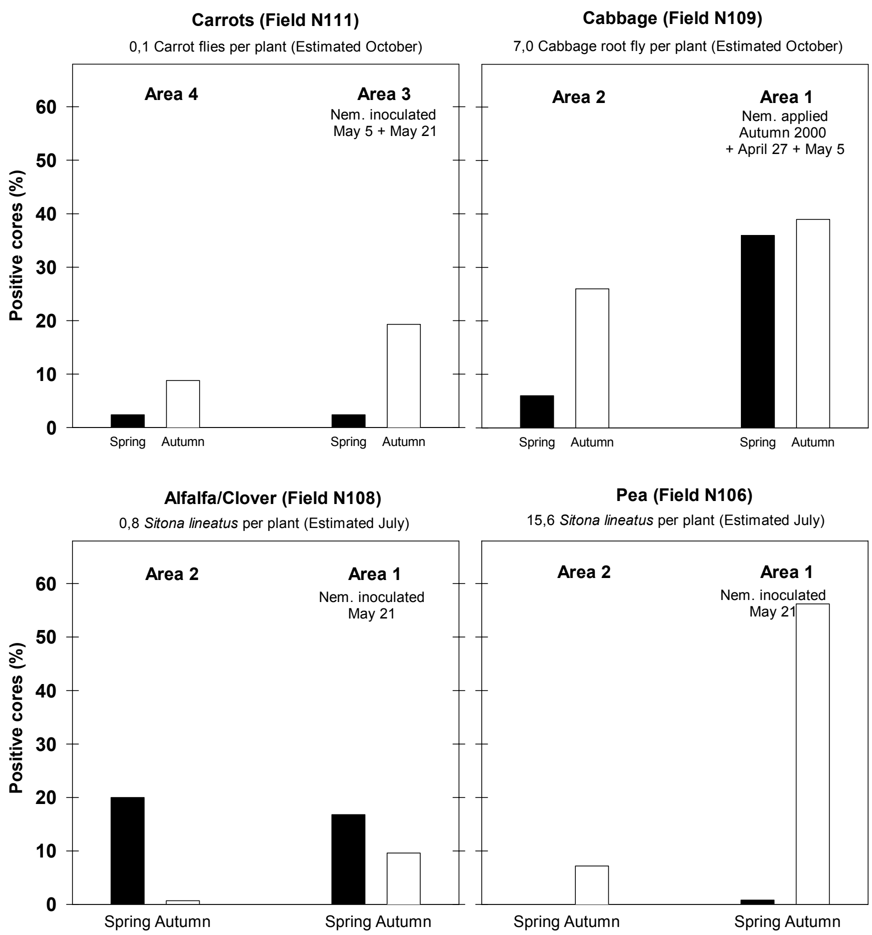


Figure 2.1. EPN and soil living plant pest at Årslev 2001

2.2. Comparing levels of EPN on neighbouring farms with different growing systems
One farm and its neighbours has so far been surveyed and here EPNs were markedly more abundant with 20% of soil cores tested positive than at the neighbour farms where only 1% of the soil cores tested positively. Additional farms will be surveyed during the autumn and winter of 2002/2003

2.3. Screening of plant species for their value of supporting populations of EPN
On the KVL experimental farm Snubbekorsgård four different catch crops were established in the autumn of 2000 and grown throughout 2001(Figure 2.2). The differences were however small and probably not statistically significant. The areas were the crops were grown will be surveyed again early 2003 to study any long-term effect of these crops. In 2002 the area has been grown with oil seed rape, pea and grain to compare the ability of these crops to support EPN populations. EPN occurrence was / will be estimated in spring and autumn. In addition, insects in oil seed rape and pea have been quantified to study the interaction between insects and nematodes.

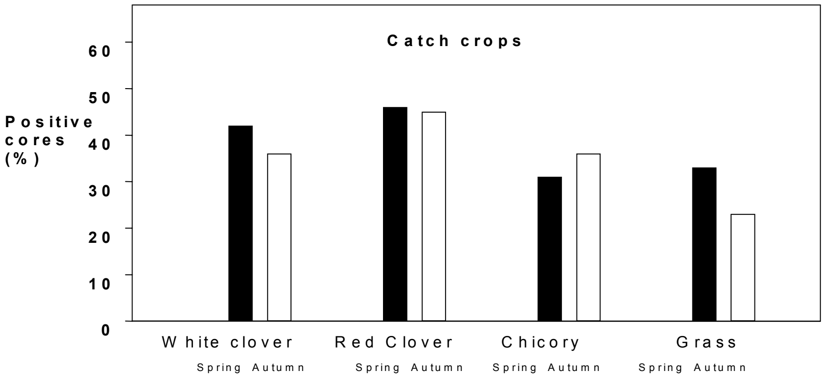


Figure 2.2. EPN and catch crops at Snubbekorsgård, KVL.

2.4. Susceptibility of beneficial arthropods to EPN
These experiments are based on field-collected insects. The insects are individually exposed to EPN in the laboratory. On average, the EPN tested only slightly added to the mortality of the ground beetles (table 1). The difference in mortality between the control and exposed groups varied for the different insects. *Agonoum*, *Harpalus* and *Trechus* seemed to be more susceptible than for instance *Carabus* and *Pterostichus* species. The experiments have been repeated and expanded in 2002 and these data have not been analysed yet before conclusions can be taken.

Table 1. Mortality of selected ground beetles after exposure to EPN.

Nematode	Insect (genus)	Number tested	Control (%)	Exposed (%)
S. feltiae	*Tenebrio* (positive control)	79	20	100
	Agonum	47	0	12
	Harpalus	82	14	29
	Trechus	70	32	55
	Calathus	16	50	75
	Carabus	21	18	20
	Pterostichus	83	46	50
	Nebria	79	45	31
S. affine	*Tenebrio* (positive control)	16	0	88
	Harpalus	30	14	25
	Pterostichus	48	25	46
	Calathus	13	13	20

WP3 Varieties, growing stability, disease resistance and quality

In 2002 five varieties of carrots, cauliflower and onions were sown/planted both in conventional and organic fields. Cauliflower and onions were grown at Research Centre Aarslev, whereas the carrot experiment was located at two commercial carrot producers on sandy soils in Jutland. Two very different varieties of carrots were tested in Aarslev in a conventional field and in our organic vegetable crop rotation. The five varieties of each species were chosen on the basis of the higher number of varieties grown in 2000. The results from 2000 were used to make sure that we could find five varieties in every crop with clearly different characteristics.

The results from 2000 and 2001 show that it is possible to grow cauliflower organically even in the summer, where the pest problems are most severe. The harvest in 2002 is ongoing in the organic trial, because the high temperatures under the net postponed the curd initiation. In 2000 the curds were small because of lack of nitrogen. This was not the case in 2001, where the harvested curds had the desired size.

The carrots grown organically in 2000 showed much less attack of cavity spot (0.7% of the roots) than the carrots grown conventional (26% of the roots). With approximately the same total yield, this led to a marketable yield of 75 ton/ha in the organic trial and only 54 ton/ha in the conventional trial. The total yield was also in 2001 almost the same in the two growing systems, and again the marketable yield was higher in the organic trial than in the conventional trial but the difference was minor. Both years attack of the carrot fly has been highest in the conventional trail.

In the onions we saw a later infection of downy mildew in the organic trial, about two to three weeks later than the conventional trial both in 2000, 2001 and 2002. Unlike carrots and cauliflower, the yield of onions was substantially lower in organic production in 2000 (42 t ha^{-1}) and 2001 (31 t ha^{-1}) than in conventional production in 2000 (78 t ha^{-1}) and 2001 (51 t ha^{-1}). The storability of onions was almost the same in the two production systems.

It is too early to judge whether some varieties are specifically adapted to organic production methods, and on the storability of carrots from the two productions systems.

WP4 Catch crops as a tool for increasing P bioavailability on soils of low P status

In 2001 the field experiment was established in the Long-term nutrient depletion trial at KVL. We selected 5 catch crop species in collaboration with DJF Aarslev, namely Chicory, Rumex, Lupine, Ryerass, Kidney vetch and a Control without any crop. In the Long-term nutrient depletion trial we placed the catch crop treatments in all plots, but chose to sample and measure in only 3 of the nutrient treatments: (A: 60N 0P 0K) (B: 60N 0P 60K) (C: 60N 10P 60K) (numbers are in kg/ha/y inorganic fertilizer). All catch crops were undersown in spring barley in 2001, and barley was harvested in August. All five catch crops were poorly establish (particularly Lupine and Rumex), because late sowing and adverse soil conditions during spring.

Aboveground catch crop biomass was sampled in late October together with soil samples in four depths to 1m. Plant samples were analysed for DW, N, P and soil for inorganic N. In February the field plots were ploughed and spring barley sown. In the subsequent growing season, plant samples were taken 4 times including at harvest.

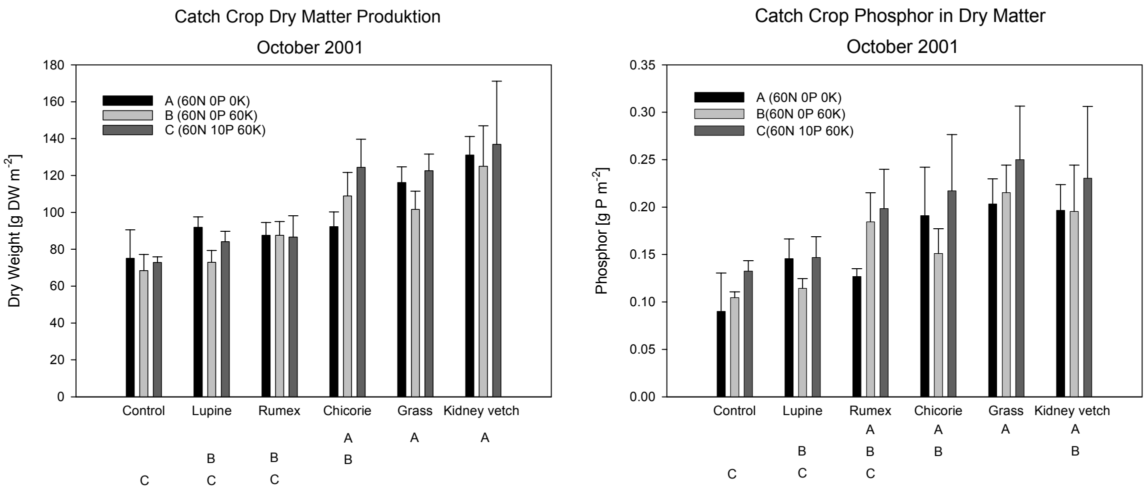
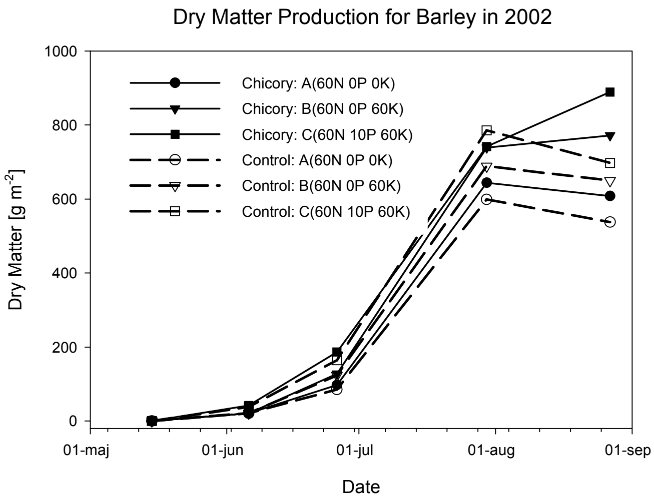


Figure 4.1. Dry Matter Production (aboveground) and Phosphorous content in plant matter. Bars: Standard error. Letters: Same letter belongs to same group (Tukey's Studentized Range Test).

Results for plant production and phosphorous content for the catch crops are shown in Figure 1. Weed and straw biomass are included in the data. There is no statistically significant difference between nutrient levels A, B and C. Ryegrass and Kidney vetch had a higher dry matter production than Control, Lupine and Rumex. Phosphorous content in catch crop dry matter (Figure 4.1, right), shows that Ryegrass accumulated significantly more P than the Control and Lupine treatments. Again, no significant difference was found between nutrient treatments A, B and C. Kidney vetch contained significantly more nitrogen than all others (data not shown). Measurement of soil inorganic nitrogen shows significantly less inorganic N under Chicory, compared to the Control (data not shown).

In Figure 4.2 subsequent spring barley dry matter production in 2002 in the Control and Chicory treatment for all 3 nutrient levels is shown. There is a significant difference between nutrient level C (60N 10P 60K) and the two others at the three first sampling dates. At the last sampling date (harvest) all three nutrient levels were significantly different from each other. Dry matter production within each nutrient level was not significantly affected by catch crop, except at the last sampling date, where Chicory was significantly higher than the Control for all 3 nutrient levels. Analysis of nitrogen, phosphorous and potassium in straw at each sampling date and grain at harvest are on-going at the time of writing.



Figur 4.2. Dry matter production for spring barley in all three nutrient levels where catch crop grown last year were Chicory or Control. Barley was sown on 15th. May.

The experiment has been repeated this year in the other half of the Long-term nutrient depletion trial. We used the same catch crops and nutrient treatments. All catch crops were well established this year, and currently (September) the catch crops visually indicate a high plant production. Thus the conditions for next years experiment looks promising.

WP5 Influence of autumn green manure crops on club root

The activities in WP5 started november 2001 where sources of inoculum of club root were collected. The main objective of activities in 2002 was to develop a patosystem for *P. brassica* with *Brassica pekinensis* as a known susceptible host plant. Part of the work with the patosytem was to develop a fatty acid based method to quantify *P. brassica* in roots. Furthermore, 10 cruceferous catch crops were planned to be examined for *P. brassica* resistance using the mentioned patosystem under green house conditions. Finally, cruceferous catch crops were planned to be established in a naturally club root infested field, in order to measure, how these catch crops are affecting the soil inoculum potential of the pathogen, which is going to be examined in 2003.

5.1. Patosystem

Inoculum of the causal agent of club root *Plasmodiophora brassica* was collected as infested soil (cabbage grower, Knud Vincent, Bisserup) and from winter rape with clubbed roots (Skanderborg). From these two sources of inoculum a patosystem with *B. pekinensis* was developed. Two different approaches were tried. Firstly, club root infested "Bisserup" soil was mixed with Flakkebjerg soil:sand mix at conc. of 10, 25, 50 and 100 % (without Flakkebjerg soil:sand) and *B. pekinensis* were used as test plant. This method showed to be useful as even the lowest inoculum concentration resulted in club root development in all 6 replicate units. In another experiment clubbed roots of winter rape collected from Skanderborg was used to extract resting spores of *P. brassica*. Resting spores were applied to sand and left to dry overnight and mixed in to Flakkebjerg soil:sand mix giving concentrations of 10^4, 10^5 and 10^6 spores g^{-1} soil. With this method none of the six plants showed any club root symptoms. Consequently, the method based on club root infested soil was chosen for the resistance experiment under controlled conditions.

5.2. Quantification of *P. brassica* in roots

Preliminary results show that roots of *B. pekinensis* infected with *P. brassica* contains high amount of the fatty acid arachadonic acid (20:4) which is not present in uninfected plants. This fatty acid has also been used to quantify other root inhabiting fungi and seems to be an ideal method to quantify *P. brassica* directly in roots as a complement to the coventionel methods such as scoring disease symptoms or measuring plant growth parameters.

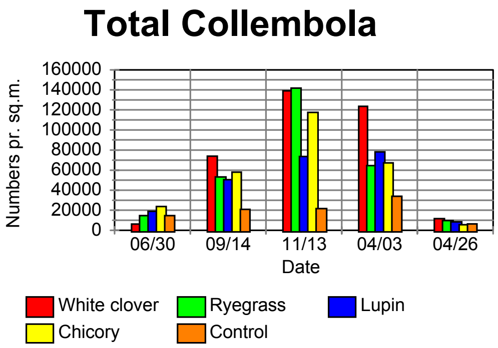
5.3. Screening for club root resistent cruciferous catch crops

A green house pot experiment using "Bisserup" club root infested soil as pathogen inoculum is currently running (august-september). The pathogen inoculum was mixed with Flakkebjerg irradiated (10 kGy) soil:sand with 0, 10, 50 and 75 % infested soil (vol/vol). The following plants were sown (25 seeds per pot) in 1.25 l pots: *Brassica pekinensis, Sinapsis alba*, *Brassica napus, Brassica campestris* var *campestris*, *Brassica oleracea* var *acephala*, *Isatis tinctoria, Camelina sativa, Raphanus sativus* and "Typhoon". The soil temperature is kept constant at 20°C. Plants are harvested 4-6 weeks after sowing and examined for club root symptoms and plant growth parameters are measured (shoot and root dry weight and root length). The pathogen is quantified in roots by the use of the signature fatty acid 20:4.

A field experiment has been established in a club root infested field (Knud Vincent, Bisserup) with the following catch crops: *Brassica pekinensis*, *Sinapsis alba*, *Brassica napus*, *Brassica campestris* var *campestris*, *Brassica oleracea* var *acephala*, *Isatis tinctoria*, *Raphanus sativus*, *Lollium perenne, Lollium multiflorum* and *Avena sativa*. The three latter plant species are included as non-cruceferous catch crops which does not host the club root pathogen. In fact growth chamber experiments with *L. perenne* have according to older literature indicated, that this species may reduce the resting spore density in *P. brassica* infested soil. Each plant species has been established in four 1.5x4 m parcels. In the spring 2003 *B. pekinensis* is going to be grown in this area to examine how the various catch crops have been affecting the soil inoculum potential of the pathogen.

WP6 The effect of catch crops on soil mesofauna and earthworms

The sampling of mesofauna and earthworms in the undersown catch crops in cereals at Research Centre Årslev was started in late June 2000, and followed up with sampling in mid September, mid November, early April 2001 and late April 2001. At all five sampling occasions the mites and Collembola were sampled and extracted. By the two last autumn sampling occasions soil samples were also taken to investigate the effect of undersown catch crops on the earthworm fauna.



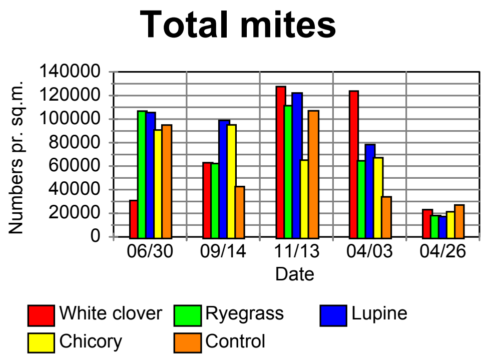


Figure 6.1. The densities of Collembolas and mites in plots with undersown nitrogen catch crops at Research Centre Årslev. Soil tillage took place between the two last sampling dates.

Some of the results are shown on the fig. 6.1 and 6.2. The densities of mites and Collembolas are remarkably high (up to 140,000 m^{-2}), probably the highest densities observed in agricultural soils in the world. Undersown catch crops caused a large increase in Collembola densities compared to the control. Some of the species occurring in high numbers are surface living and are important preys for polyphagous predators (spiders and carabid beetles), that play an important role in natural control of aphids. The results also clearly demonstrate the impact of tillage on the fauna, as the Collembola density is reduced to about one fifth, and looking at the surface living species the impact is even worse.

Concering the mites the picture is different. The densities are very high, up to about 125,000m^{-2}, but there is no clear difference between the plots with undersown catch crops and the control. Furthermore, the mites are much less affected by the tillage events than the Collembolas.

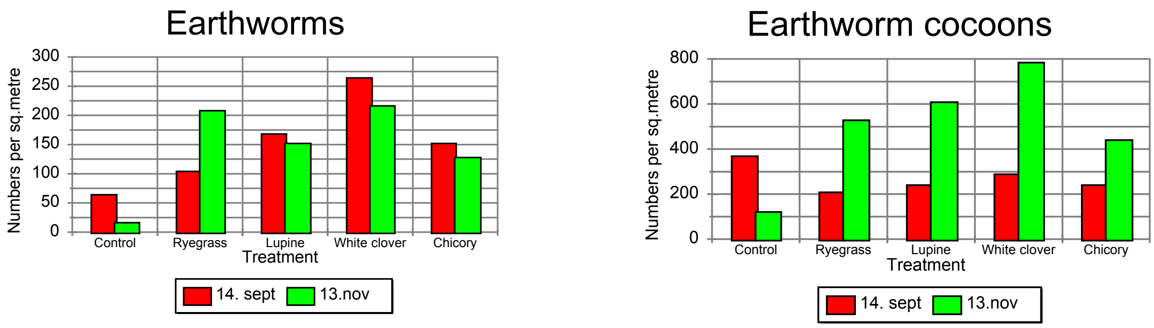


Figure 6.2. The densities of earthworms and earthworm cocoons in plots with undersown nitrogen catch crops at Research Centre Årslev during the autumn 2000.

The occurrence of earthworms is not especially high for organic fields but are clearly affected by the undersown catch crops. The densities are higher in the catch crop plots than in the control plots. In mid November the difference is close to a factor 10. The most interesting results concerning the earthworms are probably the cocoon density on 13 November. These results indicate a considerable potential for high earthworm numbers the following year.

Deliverable no 2 concerning data and a scientific paper on “the effect of deep-rooted catch crops on the soil fauna” has been merged with deliverable no. 1 concerning data and paper on “the effect of undersown catch crops on the soil fauna”. A misunderstanding in the application causes this, as the experiments in WP8 deal with different catch crops among which some are deep rooted. There are not different experiments for deep rooted and shallow rooted species. The experiments on the good soil at Research Centre Aarslev have been described above and the ones on sandy soils are being carried out in 2002/03. Therefore the two deliverables have been merged and postponed until 2003.

The misunderstanding in the application, mentioned above, left some free time in the autumn 2001, which was used to investigate the soil fauna in the deeper layers (down to 2 m) under the undersown catch crops. The rationale behind this investigation was the extremely high densities in the upper soil layers, and the knowledge about the rooting development of the catch crops. The results showed no mesofauna below 1 m. In the layer between 50 cm and 1 m the densities were low ranging between 0 and 700 springtails m^{-2} and between 0 and 3000 mites m^{-2}. The high value of 3000 m^{-2} was found under Rumex but due to large variation the difference to other catch crops was not significant. The conclusion is that the mesofauna density under undersown catch crops is not exceptionally high and we could not demonstrate any differences between the different species of catch crops.

WP7 The effect of catch crops on N and K leaching and crop production on coarse sandy soils

The second growing season in the WP7 project at Jyndevad Experimental station has now passed without major problems and with interesting results. Yields results from this year will first be available in November.

7.1. Comparison between legume catch crops and non-legume catch crops under different N and K conditions

The hypothesis of this experiment is that legume catch crops are better than non-legume catch crops to reduce K leaching losses under conditions with a low N level in the soil. A low and a high N-level were established using a grain and a legume crop, respectively and the two K levels were obtained by K exhaustion prior to the experiment and by application of KCl fertilizer. Suction cups were installed after harvest of the cover crop in 2001 and again in 2002. Every one or two weeks, from harvest to spring, soil water is sampled and analysed for nitrate-N and K content. Measurements of total N and K leaching losses for the 2001/02-season will first be carried out in 2003. The activity is carried out in collaboration with Project 1.5 ”Grain legumes and cereals – new production methods for increased protein supply in organic farming systems”, WP 2.

7.2. Legume catch crops as the only N-source.

The hypothesis of this experiment is that the N_2-fixation in the clover-mixture catch crop will be able to replace the N supply in slurry as the N source to non-fixing crops. Table 7.1 shows grain yields in the first year and yields in the dry matter (DM) production of the catch crop in the autumn. The effect of the catch crop was absent in the first year 2001 and as expected this resulted in a low yield level in treatment 3. A visual evaluation of the barley growth suggests a considerable increase in the yield level in treatment 3 in 2002. N-balances will be estimated for the three systems, and the leaching results in Figure 7.1 shows higher nitrate concentrations in the treatment without catch crop and interesting differences between the two catch crop types.

Table 7.1. Grain yields of spring barley, yield and N in the top of the catch crops (1 November) and N_{min} (nitrate + ammonium) in the soil at 0-100 cm depth (1 November), 2001.

Treatment	Catch crop	Slurry	Spring barley	Catch crop		N_{min}
			ton DM ha^{-1}	ton DM ha^{-1}	kg N ha^{-1}	Kg ha^{-1}
1	No	+	3.8^a	-	-	25
2	Ryegrass	+	3.6^a	0.8^b	16	16
3	Clover mixture	-	2.2^b	1.9^a	56	16

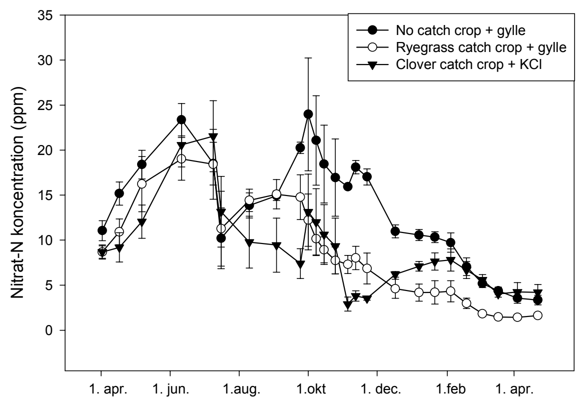


Figure 7.1. Nitrate-N concentrations measured at 1 m depth from 1 April 2001 to 1 April 2002.

7.3. Screening of catch crops

We measured significant differences between the catch crops in their autumn production in 2001 (Table 7.2) and in the growth of the following barley crop in 2002 (Figure 7.2). It appears that 1) the N-release from of the clover varieties are close to 80 kg N ha^{-1}, 2) a high production of dry matter in the autumn does not necessarily cause a high production in the following barley and 3) that the non-N_2-fixing catch crops are not able to release enough N for the barley.

Measurements of root weights at 4 different depth 0-25, 25-50, 50-75 and 75-100 cm was carried out in the autumn 2001 in all replicates of five selected treatments: without catch crop, ryegrass, white clover, chicory and kidney vetch. The main part of the root mass was found in the 0-50 cm layer and beyond 75 cm there was nothing.

Tabel 7.2. Aboveground dry matter production and N-content of different catch crops measured 1 November 2001.

N_2-fixing catch crops	KgDM ha^{-1}	KgN ha^{-1}	Non-fixing catch crops	KgDM ha^{-1}	KgN ha^{-1}
Kidney vetch	2550	60	Chicory	957	16
Red clover	2279	64	Rye/hairy vetch[1]	805	31
Persian clover	2250	55	Ryegrass	642	11
Black medic	2061	62	Sorrel	452	10
White clover	1166	39	Fodder radish	373	10
Lupine	967	27			

[1] is included in the group with N_2-fixation

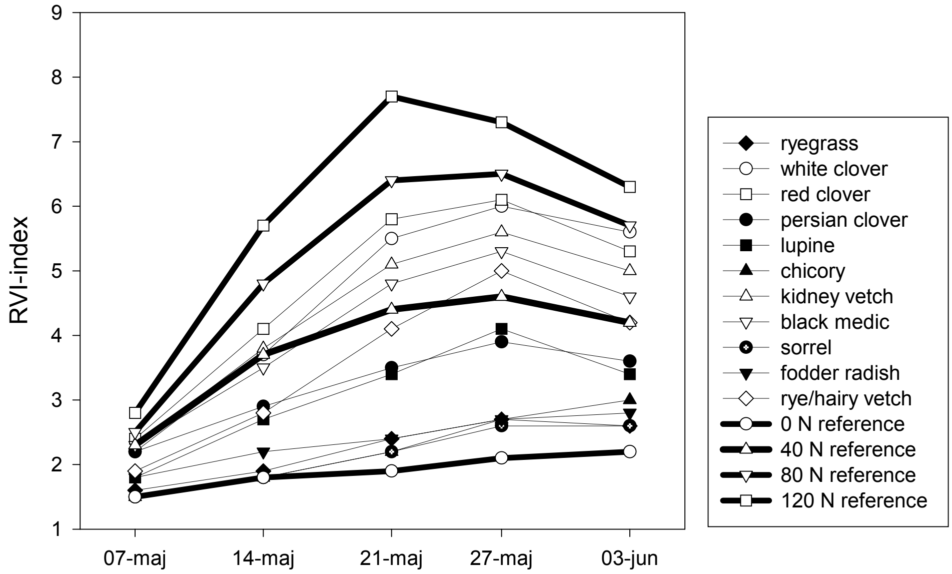


Figure 7.2. Measurements of RVI (ratio vegetation index) in 2002 in spring barley following different catch crops. The reference treatments are without catch crop and with 0, 40, 80 and 120 kg fertilizer N ha^{-1} respectively.

WP8 Very deep-rooted crops and catch crops in the crop rotation, N dynamics and modelling

8.1. Experiments with cropping sequences including very different rooting depths

This experiment is repeated twice, in the period 2000-2003 and in 2001-2004, thus no final results have been obtained yet. However, the results obtained until now are clearly promising. We have obtained the very large differences in rooting depth of catch crops grown in the first year (ryegrass <100 cm and fodder radish > 200 cm), and vegetable crops grown in the second year (figure 8.1). In the figure cabbage is shown to reach a rooting depth of almost 2.5 m, but the real rooting depth was deeper, but our minirthizotrones reach a depth of 2.4 m, and root growth beneath this depth cannot be observed. The N_{min} data show that without a catch crop in the first autumn much more nitrate N found in the 100 to 250 cm soil layer in the next spring. Measurements made after vegetable harvest show that where no catch crop had been grown, only the very deep rooted cabbage crop could deplete the soil as much of the available N was found deep in the soil (figure 8.1). Where a catch crop had been grown, also red beet with less rooting depth could deplete the soil, as little N was available below its rooting depth.

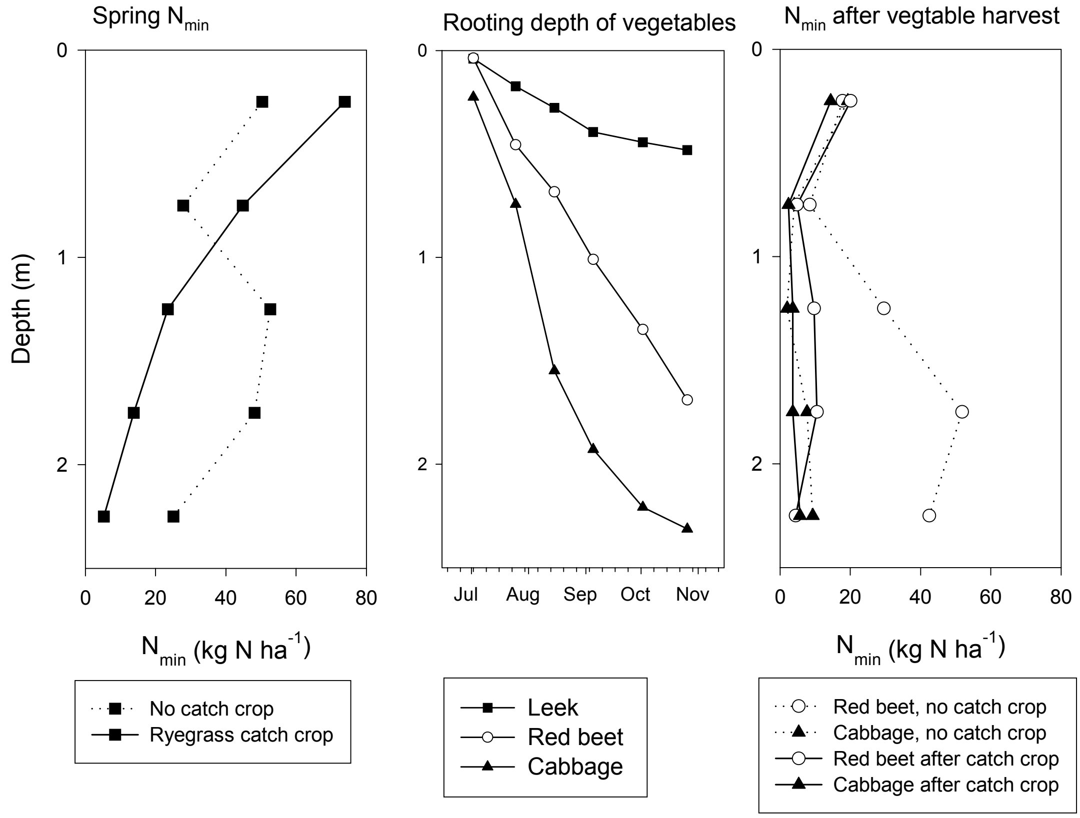


Figure 8.1. Spring N_{min} (kg inorganic N ha^{-1} per 0.5 m soil layer) before establishment of three vegetable crops, rooting depth development of the vegetables and N_{min} after vegetable harvest (only cabbage and red beet after control (bare soil) or ryegrass catch crop shown)

8.2. Undersown catch crops with deep rooting

We have now tested more than 20 plant species for their ability to grow as undersown catch crops, and measured their root growth, N uptake and depletion of the soil N pool to 2.5 m depth. Several species have been identified which work well as catch crops. The data also show large differences in rooting depth. Ryegrass and the legumes which have been tested seem only to have significant root growth within the top 100 cm of the soil. Some of the other dicot species have shown deeper rooting, and typically reaching about 150 cm during the autumn, only chicory and echium have reached 200 cm or more during the autumn. The measured N uptake has been correlated to rooting depth, and the N uptake of chicory have been 86 kg N ha^{-1} as compared to an uptake of 57 kg N ha^{-1} by ryegrass. The results of the N_{min} measurements also shown an effect of rooting depth, though this has not been as clearcut as we have previously seen in experiments with catch crops sown after harvest. Currently, the third experiment is growing in the field. Next we will select some of the most promising species for the last year of the experiment, and we will consider including different types of chicory which have until now been the most promising species.

A bachelor thesis (*Do the root development of chicory, pastinaca and ryegrass affect their suitability as catch crops*) has been made and defended in 2002 as part of this study.

8.3. Model simulation of the effect of deep-rooted crops and catch crops

This work has been initiated with a simulation study of a number of crop rotations including deep or shallow rooted crops and catch crops. These simulations have been used to illustrate the effects of catch crops on N dynamics in a crop rotation, the effect of different catch crop types, and why it is important to consider soil layers also below 1.0 m when studying catch crop effects. The results have been used in a review paper to be published in Advances in Agronomy, and for production of a general text on catch crop and green manure crops to be used in the teaching of plant nutrition at RVAU.

WP9 The effect of catch crops on sulphate leaching and availability of S for the succeeding crop

Soil and plant sampling has been carried out in the workshop area in Årslev in November 2000 and 2001 to determine the effect of catch crops on the content of leachable sulphate in the soil and the potential for S stabilization in crops. Furthermore catch crops have been sampled at Jyndevad Experimental station in 2001. The catch crops from both autumn 2000 and 2001 showed a very wide range in chemical composition regarding S content and C/S ratio (Table 1).

Table 1: Composition of catch crops

	Autumn 2000			Autumn 2001		
Catch crop	Location	S-content	C/S	Location	S-content	C/S
Fodder radish	Årslev	0.81	48	Jyndevad	0.45	84
Winter rape	Årslev	0.54	77	Jyndevad		
Chicory	Årslev	0.43	99	Jyndevad	0.28	146
Evening primrose	Årslev	0.37	118	Jyndevad		
Parsnip	Årslev	0.34	120	Jyndevad		
Ryegrass	Årslev	0.36	122	Jyndevad	0.19	226
Sorrel	Årslev	0.34	128	Jyndevad	0.23	188
Salad Burnet	Årslev	0.28	161	Jyndevad		
Medic	Årslev	0.27	172	Jyndevad	0.16	278
White clover	Årslev	0.26	173	Jyndevad	0.17	250
Kidney vetch	Årslev	0.20	221	Jyndevad	0.13	329
Lupin	Årslev	0.17	265	Jyndevad	0.17	246
Red clover				Jyndevad	0.16	276
Persian clover				Jyndevad	0.13	324
Rye/vetch				Jyndevad	0.17	222
Echium				Jyndevad	0.26	146
Lepidium campestre				Årslev	1.03	40
Barbarea verna				Årslev	0.81	50
Barbarea vulgaris				Årslev	0.93	43

There is variation in the S-content of the same catch crop depending on location. On the the sandy Jyndevad location S-contents were generally lower than on the Årslev sandy loam soil.

In spring 2001 and 2002 a pot experiment were established to determine the mineralisation of S from the different catch crops. The results from 2001 and some initial results from 2002 indicate the availability of S in the catch crops is related to the C/S ratio of the material (Figure 9.1). The C/S ratio explained 49% of the variation in the S-value of the added catch crops. It is interesting that the catch crops with the highest C/S ratios and consequently the lowest S-value are all legumes. This may have consequences for the choice of catch crops on S-deficient soils.

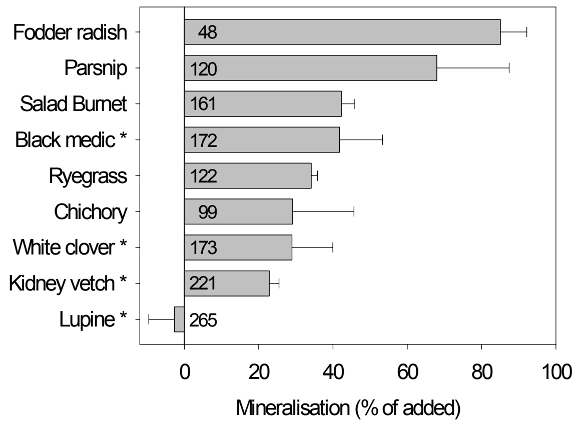


Figure 9.2. Mineralisation of catch crop S during the growing season of spring barley. Legumes are marked '*'. Inserted in bars are catch crop C/S ratios. Error bars: SE.

C.2 Fulfilment of deliverables and milestones

(To be completed for each work package)

WP1 Nitrogen relationships of vegetable crops, and project co-ordination	**Time schedule according to application**	**Deviations, if any***
Task		
1 To co-ordinate the VEGCATCH project		
2 To study rooting depth during growth and N dynamics for 6 vegetable crops		
3 To supply data on N, root growth and N dynamics for modeling (WP8 and the Project BIOMOD)		
4 To test N effects of green manure crops incorporated in the late spring		
Deliverables and milestones		
1 Papers on growth, root growth, and N dynamics of the three vegetable crops grown in 2000 and 2001.	2002	
2 Papers on growth, root growth, and N dynamics of the three vegetable crops grown in 2002 and 2003.	2004	
3 A paper on root growth of cabbage, leek and red beet from the cropping sequence exp. (see WP8)	2004	
4 A paper on legumes that are allowed to grow and fix N in the spring before vegetable crops	2003	

WP2 Entomopathogenic nematodes (EPN) in organic cropping systems	Time schedule according to application	Deviations, if any*
Task		
1 Interactions of EPN, pest insects and plants in the organic growing system at Årslev	2000-2003	
2 Comparing levels of EPN on neighbouring farms with different growing systems	2000-2003	
3 Screening of plant species for their value of supporting populations of EPN	2000-2003	
4 Susceptibility of beneficial arthropods to EPN	2001-2002	
Deliverables and milestones		
1 Presentation of the entomopathogenic part of VEGCATCH at IOBC meetings	2001	✓ 2 papers
2 Paper directed to Danish farmers and advisors on entomopathogenic nematodes in organic growing systems.	2003	
3 Scientific paper on the ability of different catch crops to enhance and support populations of entomopathogenic nematodes.	2003	Will focus more on main crops
4 Scientific paper on results from project with susceptibility of non target arthropods Presentation of results at The Danish Plant Protection Conference	2003	
5 Spring 2002, Selection of the most promising catch crops regarding their ability to enhance nematode populations.	2002	Delayed

WP3 Varieties, growing stability, disease resistance and quality	Time schedule according to application	Deviations, if any*
Task		
1 To test varieties and make guidelines for choosing varieties for organic growing		
2 To study the significance of various pests, diseases and quality defects in vegetables grown in organic or conventional production systems		
Deliverables and milestones		
1 An international scientific paper on the organic grown carrot, cauliflower and onion varieties	2004	
2 An international scientific paper on differences between organic and conventional growing of onion, carrot and cauliflower	2004	
3 A guideline for growers and advisors, describing the most important characteristics,	2003	
4 Preliminary publications, from the evaluation of carrot, cauliflower and onion varieties, every year.	2001-2004	Not started

WP4 Catch crops as a tool for increasing P bioavailability on soils of low P status	Time schedule according to application	Deviations, if any*
Task		
1 To test selected catch crop species for their P uptake capacity on a low P status soil.		
2 To quantify the influence of these catch crops on subsequent main crop yield and P uptake		

3 To quantify possible interactions between catch crop species, the crop rotation (with or without grass-clover ley) and additional P supply for the main crop.		
Deliverables and milestones		
1 Papers on the effects of undersown catch crops on P bioavailability for subsequent crops.	2003	
2 Papers for Danish organic farmers and advisors on the value of undersown catch crops as a P source in the crop rotation.	2002-2003	Not Started

WP5 Influence of autumn green manure crops on club root (*Plasmodiophora brassicae*)	**Time schedule according to application**	**Deviations, if any***
Task		
1 To identify crucifer species or genotypes with full or partial resistance to Plasmodiophora brassicae		
2 To identify crucifer catch crops that can be grown without increasing subsequent disease pressure of *P. brassicae* or can actually reduce subsequent disease pressure		
Deliverables and milestones		
1 Paper on pathogenicity of *P. brassicae* on a wide range of Brassica species. Species with high level of resistance are selected for the field trials 2003 and 2004	2002	
2 Results from the first year field experiment has been obtained.	2003	
3 Results from the second year field experiment has been obtained. Paper on effect of autumn green manure crops on *P. brassicae*	2004	
4 A guide line for using autumn green manure crops in relation to infestation level of *P. brassicae* has been publicised in a national paper Information IV has been included in the decision support system.	2004	

WP6 The effect of catch crops on soil mesofauna and earthworms	**Time schedule according to application**	**Deviations, if any***
Task		
1 To describe the effect of growing catch crops on the populations of a number of soil living animals, and to test whether important differences exist among catch crops in their effect on the soil fauna.		
2 To obtain data on the effect of catch crops on the soil fauna which can be used for modelling purposes in the BIOMOD project.		
Deliverables and milestones		
1 Scientific paper on the effect of undersown catch crops in cereals on the soil fauna	2001	Merged with deliverable 3
2 Scientific paper on the effect of deep-rooted catch crops on the soil fauna	2003	Mistake, same as 1

3 Scientific paper on the effect of catch crops at different levels of nitrogen and potassium on the soil fauna.	2004	Now planned for 2003
4 Popular scientific paper on the results.	2003	

WP7 The effect of catch crops on N and K leaching and crop production, with focus on coarse sandy soils.	**Time schedule according to application**	**Deviations, if any***
Task		
1 To test whether catch crops can significantly reduce K leaching losses on a coarse sandy soil		
2 To test N supply from undersown legume catch crops for continious grain production		
3 To identify legume- and non-legume catch crop species suitable for undersowing on coarse sandy soil.		
4 To estimate the influence of catch crop rooting depth on cation leaching from the root zone on a sandy loam soil.		Cancelled
Deliverables and milestones		
1 Paper on the effect of non-N_2-fixing and N_2-fixing catch crops on nitrate and potassium leaching on a coarse sandy soil	2004	
2 Paper on the effect of non-N_2-fixing and N_2-fixing catch crops on the yields of succeeding crops on a coarse sandy soil	2004	
3 Paper on the cation and anion balances as affected by different catch crop types on a clay soil	2004	Cancelled
4 Papers in national agronomic magazines for information about the results	2003-4	

WP8 Very deep-rooted crops and catch crops in the crop rotation, N dynamics and modelling	**Time schedule according to application**	**Deviations, if any***
Task		
1 To test the significance of including very deep-rooted crops and catch crops into cropping sequences		
2 To obtain data on root growth and soil N dynamics for validation of model simulations of deep soil N dynamics		
3 To identify plant species with very deep rooting which can be established as undersown catch crops in cereals.		
4 To utilise current knowledge and results obtained through objectives 1)-3), and simulation modelling to build a decision support system for optimal catch crop strategies.		
Deliverables and milestones		
1 Data from the cropping sequence experiment will be delivered for the BIOMOD project	2001, 2002 and 2003	Delayed
2 A paper on the effects of crops with different rooting in cropping sequences on N dynamics.	2004	
3 A paper on the rooting depth, soil depletion, N uptake and release of the undersown catch crops.	2004	

4 A paper on the value of very deep-rooted crops and catch crops in the crop rotation.	2004	
5 A paper on the developed decision support system.	2003	
6 A decision support system on optimal use of catch crops	2003	
7 Early spring, 2002: Selection of deep-rooted catch crop species to be included in the last year of the cropping sequence experiment.	2002	
8 Writing a review on catch crops and green manures for an international scientific journal, and for use in teaching agricultural students at RVAU about catch crops and green manures	2002	Added deliverable

WP9 The effect of catch crops on sulphate leaching and availability of S for the succeeding crop	Time schedule according to application	Deviations, if any*
Task		
1 To determine the ability of catch crops to reduce soil sulphate concentrations		
2 To determine the ability of catch crops to make S available for the succeeding crop through mineralization.		
Deliverables and milestones		
1 Paper on the effect of catch crops on sulphate leaching submitted to international refereed journal	2002	
2 Paper on the sulphur supplying capacity of catch crops to the succeeding crop submitted to international refereed journal	2002	
3 Paper to Danish farmers and advisors on the effect of catch crops on S utilisation	2002	

** Deviations are to be further discussed in D*

D. Description of deviations and subsequent adjustments of plans

In WP2, the paper on effect of different catch crop species on EPN (deliverable 3) will be changed to focus more on effects of main crop effects than on catch crop effects. Less work have been made on catch crop effects, as the experiments in Årslev was not well suited for these studies. The experiments made at ”Snubbekorsgård” (RVAU) indicate that catch crops may only have a small effect on EPN. At the same time, other parts of the study have shown clear effects of different main crops, and thus the paper is planned to focus more on this part of the results.

In WP3 no preliminary publications have been made yet. The original plan was too optimistic, so we have chosen not to make yearly publications, but wait until we have more results to present. The plan now is to make a publication aimed at farmers and advisors when the results from the 2002 experiments are ready.

In WP4 the first publication should have been made here in the autumn of 2002. However, the quality of the first year experiment was not very good, as the catch crops were not well established. Therefore publication is postponed until next year when the results of the present experiments will be ready.

In WP6 the publication on effects of undersown catch crops in cereals on soil fauna (deliverable 1) has not been written in 2001 as planned. The plan was to publish the data from the studies in the catch crop experiments in Årslev. However, it is now the plan to make a publication including such data both from Årslev and from Jyndevad (deliverable 3), to include the results from the two very different soil types in the paper, and therefore the paper is awaiting the data from Jyndevad, which will not be ready until the end of 2003.

In WP7 we have decided to cancel task 4 and thereby also deliverable 3. This was a small study using soil samples from the Årslev experiments. The main idea was to find out whether reduced leaching of N could also reduce the leaching of K. With less N lost as the nitrate anion, less cations must also be lost. However, data from suction cup samples of soil water from the crop rotation experiment in the DARCOF project EXUNIT, show no relationship between N and K leaching on the sandy loam soils, and the cations which are "following" nitrate in the leaching water appears to be almost exclucively Ca++ and Mg++.

In WP8 the delivery of data for modelling work in the BioMod project is delayed, as the relevant part of the modelling work in this project has been delayed. An extra deliverable which was not part of the original plan has been added. A review on *Catch crops and green manures as biological tools in nitrogen management in temperate zones* have been written and. The review has been accepted by Advances of Agronomy, and is now in press. A modified form of the review has been made for use in teaching students at RVAU about catch crops and green manures.

E. Project publications and other products

1. Articles in international, scientific journals with review procedures

*Thorup-Kristensen, K., Magid, J. and Jensen, L.S. 200X Catch crops and green manures as biological tools in nitrogen management in temperate zones. Advances in Agronomy (In press)

2. Papers presented at congresses, symposiums, etc.

**Holger Philipsen & Otto Nielsen (2001). Host potential of insects from cruciferous crops to entomopathogenic nematodes and augmentation of nematodes through oil seed rape growing. X meeting of the IOBC, Athens, Greece

*Otto Nielsen (2001). Entomopathogenic nematodes in agricultural cropping systems. Society of Invertebrate Pathology, Holland

*Eriksen J. (2001) Effects of timing of sulfur application and nitrogen fertilization on yield and quality of barley. Book of abstracts from COST Action 829 meeting Sulfur-Nitrogen Interactions in Plants. p. 29

3. Reports, articles in agricultural journals, etc.

**Thorup-Kristensen, K. 2001. Roddybder i grønsager. Miljøprojekt nr.: 588. Miljøstyrelsen. pp. 16.

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

The experiments of the VegCatch project and the preliminary results have been presented orally at many occasions. Many of the participating scientists have been active within organic farming research for a number of years, and have good contacts and many opportunities for presenting the project at public meetings or field days. The activities in Årslev on crop rotation, catch crops, green manures and root growth of vegetables has been presented as part of a TV series (Beretninger fra økoloand) on organic farming. The combination of RVAU and DIAS researchers in the project promote the use of the results also for agricultural students at RVAU.

F. Scientific education

Julie Schou Christensen, RVAU, made her masters thesis: *Root systems of vegetables and root development in relation to nitrogen distribution in the soil profile (Grønsagers rodsystemer og roducvikling i forhold til kvælstoffordelingen i jordprofilen)* on the experiment on root growth of red beet, celeriac and sweet corn in WP1. The thesis was defended in 2001. The supervisors were Lars Stoumann Jensen (RVAU) and Kristian Thorup-Kristensen (DIAS).

Karsten Bach, RVAU, made his bachelor thesis: *Do the root development of chicory, pastinaca and ryegrass affect their suitability as catch crops (Har rodudviklingen ved cikorie, pastinak og rajgræs betydning for deres evne som fangafgrøder)* on the screening experiment on undersown nitrogen catch crops in WP8. The thesis was defended in 2002. The supervisors were Andreas de Neergaard and Jacob Magid (RVAU) and Kristian Thorup-Kristensen (DIAS)

Oskar Sigmarsson og Morten Andersen, finished their study as engineers at Odense Teknikum with the thesis: *Measurements of nitrate in agricultural soil by measuring electrical conductivity (Måling af nitrat i landbrugsjord ved hjælp af ledningsevne)* using soil samples from WP8 for their measurements. The thesis was defended in 2002. The supervisors were Steffen Peter Skov (Odense Teknikum) and Kristian Thorup-Kristensen (DIAS)

Rikke Jensen and Hanne Gundersen (RVAU) are doing their bachelor thesis on two years results on root growth and N dynamics in vegetable crops from WP1. Supervisors are Lars Stoumann Jensen (RVAU) and Kristian Thorup-Kristensen (DIAS).

G. National and international cooperation

Cooperation with other DARCOF projects:

There are cooperation with several of the other DARCOF projects, but mainly with:

- **DARCOF2-project Exunit (IV.23):** Most of the experiments within the VegCatch project are made within the crop rotation areas of the Exunit project. Especially the crop rotations at Recearch Centre Årslev (Vegetable rotation on sandy loam soil) and at Jyndevad (grain production rotation at sandy soil) are used. Data from the rotations will also be used, especially data from the Årslev rotation will be used in the modelling work in WP8.
- **DARCOF2-project BioMod (I.15):** Data on root growth from some of the activities within VegCatch (WP1 and WP8) will be used for modelling purposes in the BioMod project, and there will be co-operation also on the modelling activities (WP8).
- **DARCOF2-project Genesis (I.5):** The work on catch crops on N and K dynamics on sandy soil (WP7) is made in close cooperation with experiments within the Genesis project.

Cooperation with other Danish projects

- **SJVF-project: Uptake of nitrogen by deep roots – the key to reducing nitrogen leaching losses from agriculture (*Optagelse af kvælstof i dybe rødder – nøglen til reduktion af kvælstofudvaskningen fra jordbruget*):** In this project the ability of a number of crop species to take up nitrogen from soil layers below 1.0 m will be studied by uptake of ^{15}N placed at various depths relative to the rooting depths observed by the minirhizotrons.

- **Testing of vegetable varieties:** At DJF, Department of Horticulture we are testing varieties of vegetable crops in co-operation with the Danish vegetable growers organisations and the see companies. The comparison of vegetable varieties in organic and conventional production (WP3) is done in close co-operation with this existing project.
- **Net covering of cauliflower:** The work on organic cauliflower production (WP3) is done in co-operation with a project on Net covering of cauliflower to prevent pest attack, financed by the Danish Environmental Protection Agency.

International cooperation

- **EUROTATE_N, Development of a model based decision support system to optimise nitrogen use in horticultural crop rotations across Europe:** Kristian Thorup-Kristensen is a partner in this project which will start January 2003. Data from a number of the experiments made in the VegCatch project will be used for development and validation of the model, and in this project further experiments will be made to study the carry over of N from one crop to next years crop. This project will start in the beginning of 2003.
- **Optimal crop rotation for yield and cropping stability in organic vegetable production (*Optimalt vekstskifte for sikker økologisk grønnsakproduksjon*):** Kristian Thorup-Kristensen is participating in this Norvegian project associated as advisor.
- **The ecology of the cropping system; green manure as a multifunctional tool in vegetable production *(Odlingssystemets Ekologi, gröngödsling som mångfunktionellt "redskap" i grönsaksodlingen)*:** In this project financed by the Sweedish research council (FORMAS), studies of the effect of cover crops or green manures between rows of vegetable crops will be made. The goal is to reduce the occurrence of pests and diseases, and to improve plant nutrient husbandry in organic crop rotations. Studies within this project of the competition between the vegetable crops and the cover crops, with particular reference to root competition will be made in Årslev. Birgitta Båth from the Sweedish Agricultural University, who is working as a Post Doc on the project, will come to work in Årslev for several periods during the project.
- **Cost-850, Biocontrol Symbiosis:** Otto Nielsen and Holger Philipsen are members of the management comity of Cost-850, Otto Nielsen is co-convener of working Group 4 "Interactions with Soil Biota". Holger Philipsen is convener of Working Group 5 "Socio-economic aspects".
- **COST action 829 "Fundamental, Agronomical and Environmental Aspects of Sulfur Nutrition and Assimilation in Plants":** Jørgen Eriksen is a member of the management comity of Cost-829.
- **Cost-631, Understanding and Modelling Plant-Soil Interactions In the Rhizosphere Environment:** Kristian Thorup-Kristensen and Niels Erik Nielsen are members of the Management Comity of Cost-631.

H. Critical reflection on the project

Most of the research within the VegCatch project was planned at a relatively detailed level already during the project application phase. This is due to two main factors. For most of the participants, the work within the project is part of a continued development of their main research area, therefore good planning and formulation of rather precise hypotheses was possible. Further, most of the field experiments run for at least two years, and to achieve replications also in years, they will thus take a minimum of three years to perform. This is very different from other sorts of experiments which can be performed within weeks or months, and where new experiments are planned on the basis of the results of the first. Experiments with a duration of years as most of the VegCatch experiments do not allow such an iterative process even within a five-year project period, i.e. the plans can and must be relatively firm from the beginning.

At present, the original plans have largely been followed. A few experiments have partly failed, and a few changes in the plans have been made due to results and new experience from the project itself or from other projects. We have not made any significant changes due to changes in "the world around us". The project is aimed at improving the possibilities for producing different species of sales crops, especially vegetable crops. Though some diversification of the number of vegetable crops produced seem to have occurred since the project application was made, we still believe that these possibilities need to be further developed, and that the approaches we take in the project are relevant. We have new ideas and problems we would like to work on, but we think that the originally planned experiments still are the most important scientific questions for us to pursue within the framework of the VegCatch project.

The project is related to a number of other projects that we participate in, some of which have been initiated after the VegCatch project (se part G on national and international cooperation above). In this way, new ideas are taken up, though not within the VegCatch project.

We believe that the interdisciplinary approach of the project is very valuable. Really interdisciplinary studies are made in some parts of the project, e.g. in the modelling activities, in the studies of the effect of catch crop treatments (WP7 and WP8) on factors such as soil fauna (WP2 and WP6) and effects on soil S dynamics (WP9). Not all parts of the project are working that closely together. Ideally, there should have been more really interdisciplinary work within the project. It would probably be ideal if all partners were involved in interdisciplinary activities, while at the same time they had room to work in depth with their own discipline. But even though VegCatch is a big project, the resources for each of the 9 work packages are limited and strict priorities had to be made.

Still, by being in the same project, important knowledge and understanding of other aspects of the system are being communicated among the participants. It also adds to the sense of the participants, that they are not just solving isolated problems, but are looking at solutions, which must function together with other factors to improve the system as a whole, and this is a very important element in organic farming research.

At this stage of the project we have produced relatively few publications. Regarding publications in scientific journals and in proceedings from workshops etc. this is natural, as very few final results are ready yet. The experiments and their preliminary results have been presented orally to many users (farmers, advisors, agricultural students, etc.) at meetings, lectures and field days. However, a higher number of publications in e.g. farmer's journals aimed at the users and other activities presenting the project as a whole to farmers and advisors could have been produced. This is an important priority for the next year. As the project has progressed, and more conclusions can be drawn from the experiments, it will also become easier to produce such publications.

8. Budget

A. Account for any change in budgets

B. Budget for the whole project (1.000 DKK)

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

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	38.5	31.9	23.4	20		113.8
Technical personnel	27.8	29.5	23	9		89.3

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	1420	1310	1063	1007		4800
Technical personnel	761	793	659	255		2468
Other operational costs	510	455	318	152		1435
Equipment	0	0	0	0		0
Others (please specify)	199	201	214	75		689
Direct costs	2890	2759	2254	1489		9392
Indirect costs (20% of direct costs)	578	552	451	298		1879
Total	3468	3311	2705	1787		11270

Comments:

9. Signatures and stamps

Name	Institute	Date	Signature
Head of project			

Appendix I. Detailed budget

A. Budget for each participating institute (1.000 DKr)

Danish Institute of Agricultural Science

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	20.5	17.4	16.9	20		74.8
Technical personnel	27.5	25.5	20.5	9		82.5

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	806	723	747	925		3201
Technical personnel	669	655	552	255		2129
Other operational costs	380	341	249	149		1121
Equipment						624
Others (please specify)	174	181	194	75		
Direct costs	2029	1900	1742	1404		7075
Indirect costs (20% of direct costs)	405	381	348	280		1414
Total	2434	2281	2090	1684		8489

Comments:

Royal Veterinary and Agricultural University

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	18	14.5	6.5			22.5
Technical personnel	0.3	4	2.5			6.8

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	557	527	253			1337
Technical personnel	5	93	59			157
Other operational costs	114	106	61			281
Equipment						
Others (please specify)	25	20	20			65
Direct costs	701	746	393			1841
Indirect costs (20% of direct costs)	91	150	78			368
Total	842	896	471			2209

Comments:

National Environmental Research Institute

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	1,6	1,6	1,6	2,0		6,8
Technical personnel	4,0	2,0	2,0	0,0		8

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	57	60	63	82		262
Technical personnel	87	45	47	0		179
Other operational costs	16	8	8	3		35
Equipment						0
Others (please specify)	0	0	0	0		0
Direct costs	160	113	118	85		476
Indirect costs (20% of direct costs)	32	23	24	17		96
Total	192	136	142	102		572

Comments:

B. Budget for each participating department (1.000 DKK)

Danish Institute of Agricultural Science, Department of Horticulture

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	13	6	10.5	14		43.5
Technical personnel	15	10	9.5	4		38.5

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	514	255	462	645		1876
Technical personnel	363	257	255	113		988
Other operational costs	252	124	107	54		537
Equipment	0	0	0	0		0
Others (please specify)	162	132	140	60		494
Direct costs	1291	768	964	872		3895
Indirect costs (20% of direct costs)	258	154	193	174		779
Total	1549	922	1157	1046		4674

Comments:

Danish Institute of Agricultural Science, Department of Plant Protection

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	0.5	2	2	3		7.5
Technical personnel	0	4	5	3		12

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	19	85	89	140		333
Technical personnel	0	103	135	85		323
Other operational costs	0	111	113	90		314
Equipment						0
Others (please specify)	3	10	35	15		63
Direct costs	22	309	372	330		1033
Indirect costs (20% of direct costs)	4	62	74	66		206
Total	26	371	446	396		1239

Comments:

Danish Institute of Agricultural Science, Department of Crop Physiology and Soil Science

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	7	9.4	4.4	3.0		23.8
Technical personnel	12.5	11.5	6	2		32.5

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	273	383	196	140		992
Technical personnel	306	295	162	57		820
Other operational costs	128	106	29	5		268
Equipment	0	0	0	0		0
Others (please specify)	9	39	19	0		67
Direct costs	716	823	406	202		2147
Indirect costs (20% of direct costs)	143.2	164.6	81.2	40.4		429.4
Total	859	988	487	242		2576

Comments:

Royal Veterinary and Agricultural University, Department of Ecology, Zoology section:

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	10	9,0	3,5			27
Technical personnel	0,3	2,0	1,5			11

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	322	346	136			804
Technical personnel	5	42	32			79
Other operational costs	50	50	28			128
Equipment						0
Others (please specify)	10	10	10			30
Direct costs	387	448	206			1041
Indirect costs (20% of direct costs)	78	90	41			209
Total	465	538	247			1250

Comments:

Royal Veterinary and Agricultural University, Department of Agricultural Science, Plant Nutrition and Soil Fertility Laboratory section

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	8,0	5,5	3,0	0,0		16,5
Technical personnel	0,0	2,0	1,0	0,0		3

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	235	181	117	0		533
Technical personnel	0	51	27	0		78
Other operational costs	64	56	33	0		153
Equipment						0
Others (please specify)	15	10	10	0		35
Direct costs	314	298	187	0		799
Indirect costs (20% of direct costs)	13	60	37	0		160
Total	377	358	224	0		959

Comments:

National Environmental Research Institute, Department of Terrestrial Ecology

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	1,6	1,6	1,6	2,0		6,8
Technical personnel	4,0	2,0	2,0	0,0		8

Year:	Consump-tion before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	57	60	63	82		262
Technical personnel	87	45	47	0		179
Other operational costs	16	8	8	3		35
Equipment						0
Others (please specify)	0	0	0	0		0
Direct costs	160	113	118	85		476
Indirect costs (20% of direct costs)	32	23	24	17		96
Total	192	136	142	102		572

Comments: