Danish Research Centre for Organic Farming

Annual Status Report 2001 and Application for Continuation in 2002

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The Directorate for Food, Fisheries and Agro Business
under the Danish Ministry of Food, Agriculture and Fisheries

1. Research program

Research in organic farming 2000-2005 (DARCOF II)

2. Project title and number

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

3. Head of project

Kristian Thorup-Kristensen, Head of Research Group,
Danish Institute of Agricultural Sciences, Department of Horticulture, P.O.Box 102,
DK-5792 Aarslev.
Phone.: 63 90 43 43, Fax: 63 90 43 94
E-mail: kristian.thorupkristensen@agrsci.dk

4. Participating institutes

Danish Institute of Agricultural Sciences:
Department of Horticulture, P.O.Box 102, 5792 Aarslev.
Department of Crop Protection, Flakkebjerg, 4200 Slagelse
Department of Crop Physiology and Soil Science. PO Box 50, 8830 Tjele

Royal Veterinary and Agricultural University:
Department of Ecology, Zoology section, Thorvaldsensvej 40, 1871 Frederiksberg
Department of Agricultural Science, Plant Nutrition and Soil Fertility Laboratory section, Thorvaldsensvej 40, 1871 Frederiksberg

National Environmental Research Institute
Department of Terrestrial Ecology, Vejlsøvej 25, P.O.Box 314, DK- 8600 Silkeborg

5. Contact persons

Kristian Thorup-Kristensen (Project leder),
Danish Institute of Agricultural Sciences, Department of Fruit, Vegetable and Food Science,
P.O.Box 102, DK-5792 Årslev.
Tlf.: 63 90 43 43, Fax: 63 90 43 94 E-mail: kristian.thorupkristensen@agrsci.dk

Lars Bødker,
Danish Institute of Agricultural Sciences, Department of Crop Protection, Flakkebjerg,
DK-4200 Slagelse.
Tlf.: +45 58113300, Fax: 58113301, E-mail: lars.bodker@agrsci.dk

Lars Stoumann Jensen,
Plant Nutrition and Soil Fertility Laboratory, Department of Agricultural Sciences, The Royal Veterinary and Agricultural University,
Thorvaldsensvej 40, DK-1871 Frederiksberg C., Denmark.
Tlf.: 35 34 28 70, Fax: 35 34 28 70, E-mail: LSJ@KVL.DK

Jørgen Eriksen,
Danish Institute of Agricultural Sciences, Dept. of Crop Physiology and Soil Science.
PO Box 50, DK-8830 Tjele.
Tlf: 89 99 19 00, Fax: 89 99 17 19. E-mail: Jorgen.Eriksen@agrsci.dk

Holger Philipsen,
Institute of Ecology, Zoology Section, Royal Veterinary and Agricultural University,
Thorvaldsensvej 40,3 DK-1871 Frederiksberg, Denmark.
Tel +45 35 28 26 87. Fax +45 35 28 26 70. E-mail hph@kvl.dk

Jørgen Aagaard Axelsen,
National Environmental Research Institute, Department of Terrestrial Ecology,
Vejlsøvej 25, P.O.Box 314, DK- 8600 Silkeborg, Denmark.
E-mail jaa@dmu.dk

6. Other project staff

Gitte Kjeldsen Bjørn,
Danish Institute of Agricultural Sciences, Department of Fruit, Vegetable and Food Science,
P.O.Box 102, DK-5792 Årslev.
Tlf.: 63 90 43 43, Fax: 63 90 43 94 E-mail: gittek.bjorn@agrsci.dk

Jakob Magid and Niels Erik Nielsen,
Plant Nutrition and Soil Fertility Laboratory, Department of Agricultural Sciences, The Royal Veterinary and Agricultural University,
Thorvaldsensvej 40, DK-1871 Frederiksberg C., Denmark.
Tlf.: 35 34 28 70, Fax: 35 34 28 70

Margrethe Askegaard,
Danish Institute of Agricultural Sciences, Dept. of Crop Physiology and Soil Science.
P.O. Box 50, DK-8830 Tjele.
Tlf: 89 99 19 00, Fax: 89 99 17 19. E-mail: Margrethe.Askegaard.agrsci.dk

Otto Nielsen,
Department of Ecology, Zoology Section, Royal Veterinary and Agricultural University,
Thorvaldsensvej 40,3 DK-1871 Frederiksberg, Denmark.
Tel +45 35 28 26 87. Fax +45 35 28 26 70. E-mail on@kvl.dk

7. Start of project: 2000
End of project: 2004

8. Annual report/Application for continuation in 2001

A. Objectives and expected achievements (from application)

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 faunal 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

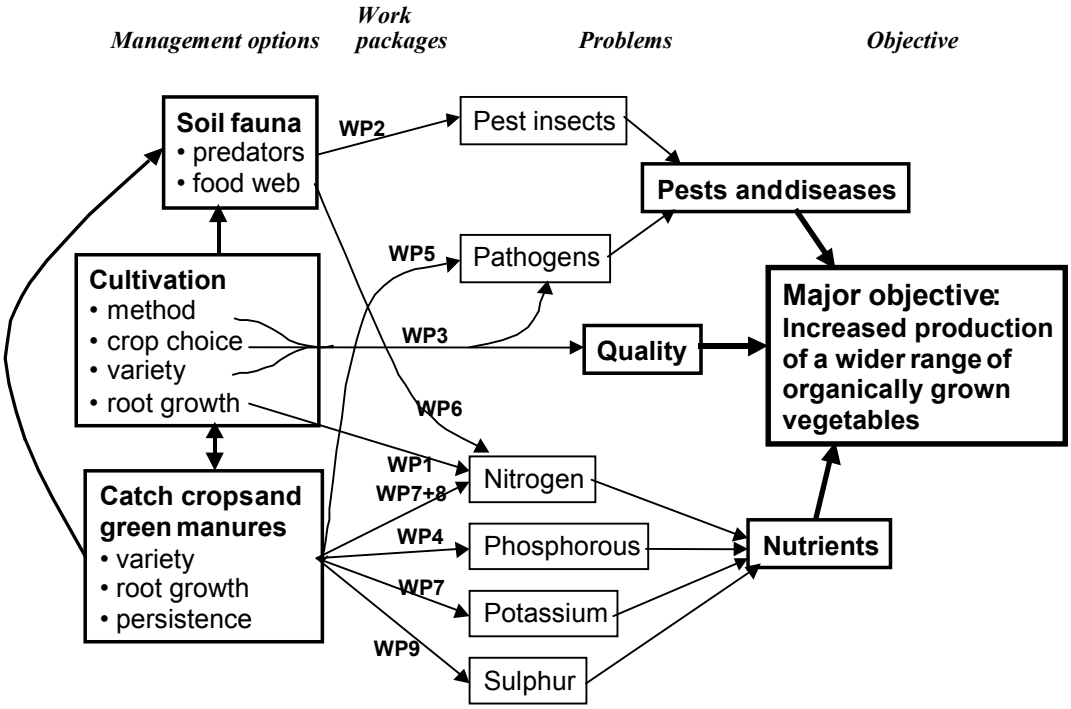

Figure 1. Overview of the major problems, management options and their interaction in relation to an increased production of organic vegetables. The figure is not a representation of all interactions, only the most important ones addressed in this project have been included. WP refers to the work packages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

B. Project summary (from application)

The development of organic vegetable production in Denmark is slowed down by the fact that the range of species grown in substantial amounts is not very large. The major problems 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 leach-

ing 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 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.

In the "Introduction" below, we have described in more detail how the project is organised, the main reasons for the chosen research strategy, and a short introduction to the different subjects addressed in the project. In "State of the art" we have described the background for each of the 10 Work Packages we propose, and the goals and methods of each Work Package are presented in "Description of Work Packages".

Table 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*)	Lars Bødker	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

* Responsible participants are underlined

C. Progress

According to the plan, all work packages except WP5 has now been started, but they are at various stages, and in several of them very few or no results have been obtained yet. In other WPs we have obtained the first results, and generally the first results have been quite promising, as described below. Apart from minor deviations, as discussed in the text on each WP, the project is running according to schedule.

We had a meeting for all participants in the project in the spring, and are planning a two-day workshop within the project this winter. The project covers a number of very different topics, and the need for general co-ordination across the whole project is limited. However, a lot of interaction is going on, as many of the WPs are working together, using e.g. the same field experiments for various measurements.

Even though the need for general co-ordination within the project as a whole is limited, we believe that it will be valuable to bring all scientists within the project together for a two day seminar every year, to get presentation and discussion across the very different topics and disciplines involved. At this meeting this year we will also decide on how to present the project as a whole to relevant users. As results from the different WPs are now starting to appear, such presentation now becomes relevant.

Two students from KVL are now working on the project, one working on her M.Sc. thesis and the other working his B.Sc. thesis.

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

WP1 Nitrogen relationships of vegetable crops
Measurement of the first 3 vegetable crops (red beet, selery, and sweet corn) to be studied for root growth and N relationships is just about to be finished in the field. A M.Sc. student from KVL (Julie Schou Christensen) has been working with this project and is making her dissertation on the results of the root and N studies. The experiment has gone well, apart from a bad establishment of sweet corn in 2000, due to bird damage and cold weather during early growth. The results show that the three vegetable crops have very different rooting patterns. Red beet have a medium deep rooting, reaching depths of more than 150 cm, and showing a relatively even distribution of the roots in the soil. Both sweet corn and celery showed shallow rooting with rooting depths of only about 50 cm, though the better growing sweet corn crop in 2001 has reached a little deeper. The rooting pattern of both these crops showed much more roots beneath the crop row than in the interrow soil. Selery show an unusual rooting pattern with very high root densities below the plants down to approx. 40 cm, and then only few roots below this depth. N measurements show that red beet was able to deplete the soil effectively both in the upper soil layers and down to 150 cm. Sweet corn on the other hand left very high amounts of available N even in the uppermost soil layers; it will be interesting to see whether this result is repeated again in 2001 where the sweet corn crop was growing much better. Due to the shallow rooting celery and sweet corn was clearly not able to utilise N leached to larger soil depths after autumn incorporation of the preceding green manure crops. During the next two years it is planned to make similar measurements on potatoes, Chinese cabbage, and squash.
Apart from these crops, root growth and soil depletion by leek and white cabbage is also measured in the “cropping sequence experiment” in WP8. The measurements on these two crops has started this year and will be repeated in 2003. The preliminary results show leek to be quite shallow-rooted, with a rooting pattern much like that of celery, whereas white cabbage is found to be very deep-rooted and to reach a depth of at least 240 cm which is our maximum measuring depth.
The experiment with “spring green manure” has not gone very well. One of the two legume species was winter killed, and could not continue growth in the spring. Due to a mistake only the early spring and early May incorporations the other legume (white clover) were made, not the late May incorporation. We will thus only make a simple test of N effect of the relevant treatments this year. The experiment will be repeated next year, and depending on next years results we may repeat it with just one legume species also in 2003.

WP2 Entomopathogenic nematodes in organic cropping systems
The work was initiated in the autumn of 2000 but the main activities have been in the growing season of 2001. Since the main purpose of this working package is to follow nematode populations over time, one growing season can only provide limited results.
Nematodes have been monitored at the experimental site at Årslev, at the KVL-farm “Snubbekorsgård” and on an organic grown farm “Hegnstrup” and its neighbours.
Pre-screening of the Årslev soil was carried out in the autumn of 2000. It was observed that the natural level of nematodes was very low. For that reason nematodes have been released in the autumn of 2000 and again in the spring of 2001. The nematodes released in 2000 have established well (monitored spring 2001) whereas it is unknown how well the spring released nematodes have established (autumn screening 2001 is ongoing). At Årslev, nematode monitoring is carried out in four of the six fields (cabbage, carrots, alfalfa/clover and pea). In each of these fields, insects have been quantified - mainly weevils in alfalfa/clover and pea - or are going to be quantified - mainly cabbage root flies and carrot flies in cabbage and carrots - and related to nematode occurrence.

At Snubbekorsgård, nematode monitoring is based on the natural occurring nematodes. Nematodes have been quantified in the autumn of 2000 and in the spring of 2001. The autumn screening of 2001 is ongoing. The occurrence of nematodes will be related to four different catch crops (red clover, white clover, grass, chicory). This experiment will be end with a screening in the autumn. Meanwhile, new experiments have been started to supplement this years experiments.
At Hegnstrup, nematode occurrence was compared to nematode occurrence at two neighbouring farms last winter. Nematodes were frequently occurring at Hegnstrup, whereas nematodes were almost absent in the soils of the neighbouring farms. The nematode populations will be followed and similar work will be carried out at other sites in the coming winter.
During the summer of 2001 ground beetles have been sampled and exposed to entomopathogenic nematodes. In general, the species tested avoided infections by the nematodes, but exceptions were seen. The data have not been analysed yet - for instance to test whether the nematodes caused an increase in mortality. Similar experiments will be carried out in 2002.

WP3 Varieties, growing stability, disease resistance and quality
In 2001 five varieties of carrots, cauliflower and onions were sown/planted both in conventional and organic fields. Cauliflower and onions were grown at Research Center Aarslev, whereas the carrot experiment was located at two commercial carrot producers on sandy soils in Jutland, as the soil in Aarslev is not well suited for carrot production. Anyhow, two 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 was 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 in the summer, where the pest problems are most severe. 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 (26,4 % 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.
In the onions we saw a later infection of downy mildew in the organic trial, about two weeks later than the conventional trial. Unlike carrots and cauliflower in 2001, the yield in the organic trial was substantially smaller in organic production (42 t ha^{-1}) than in conventional production (78 t ha^{-1}), as also observed in our organic vegetable crop rotation.
It is too early to judge whether some varieties are specifically adapted to organic production methods, and on the storability of onions or carrots from the two production systems.

WP4 Catch crops as a tool for increasing P bioavailability on soils of low P status
Research Assistant Anders Pedersen has been employed part-time on the project. The field experiment has been established in spring 2001 according to schedule in the Long-term nutrient depletion trial, KVL, with a number of under-sown catch crops in barley. Catch crops were established in all treatments of the Long-term nutrient depletion trial, however only a limited number of the treatments (3) will be sampled subsequently. Establishment of the catch crops was relatively poor, due to fairly late sowing.

WP5 Influence of autumn green manure crops on club root
Has not started yet.

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. The last sample in April 2001 was carried out in order to investigate the effect of tillage on the fauna in catch crops. At all five sampling occasions the mites and Collembola were sampled and extracted. By the two last sampling occasions soil samples were also taken to investigate the effect of undersown catch crops on the earthworm fauna.

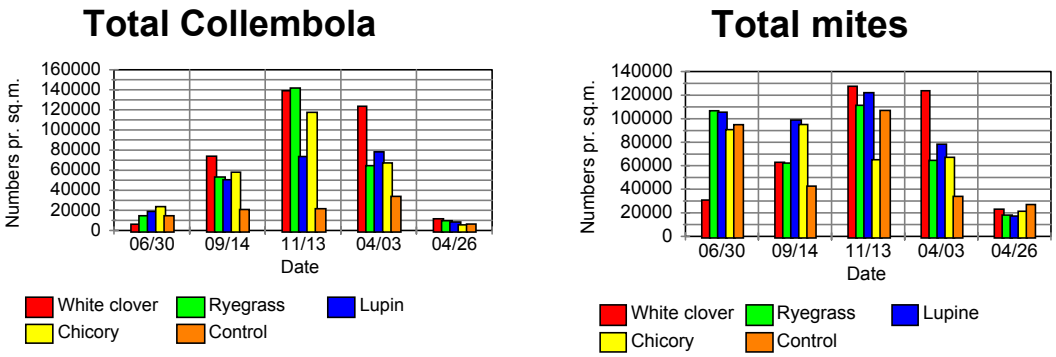

Figure 6.1. The densities of Collembolas and mites in plots with undersown nitrogen catch crops at Research Centre Årslev. Soil tillage took place between the two last sampling dates.

Some of the results are shown on the fig. 6.1 and 6.2. The densities of mites and Collembolas are remarkably high. Undersown catch crops caused a large increase in Collembola densities. 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 particular species the impact is even worse. Some of the surface living species are reduced from between 5,000 and 15,000 m^{-2} to almost nothing. These severe effects are stronger than normally seen in connection with tillage events, and are most likely due to both rotary cultivation and ploughing.

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.

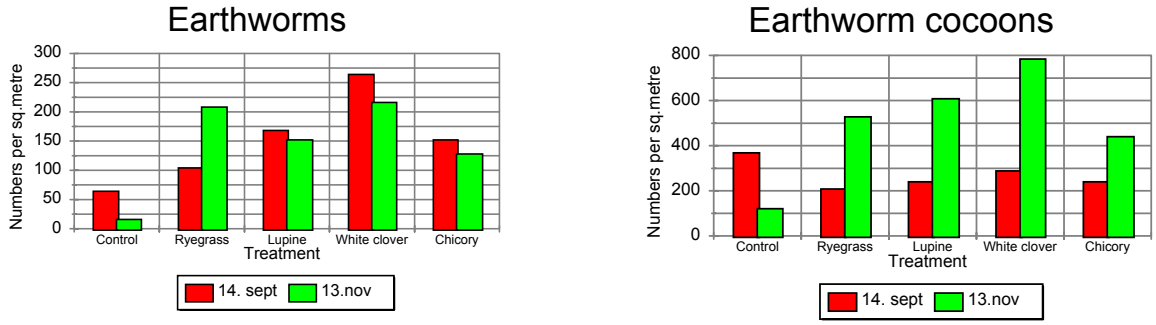

Figure 6.2. The densities of earthworms and earthworm cocoons in plots with undersown nitrogen catch crops at Research Centre Årslev during the autumn 2000.

The occurrence of earthworms is also clearly affected by the undersown catch crops. The densities are much 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.

WP7 The effect of catch crops on N and K leaching and crop production on coarse sandy soils
According to the plan three field experiments at Jyndevad Experimental station were initiated in the spring and the main crop as well as the catch crops were well established. The fields were irrigated with about 30 mm four times during the growing season. Blind and weed harrowing were performed until sowing of the catch crops at growth stage BBCH 31.

Comparison of K effects of legume and non legume catch crops under different N and K conditions.
A low and a high N-level were established using a grain and a legume crop, respectively. Prior to the start of the experiment the area was covered by grass-clover for cutting in order to reduce the soil K-status. The high K level was obtained by application of 80 kg K ha^{-1} in KCl (49%). Suction cups were successfully installed at 1 m depth in 2 of the 4 replicates (3 cups per plot x 24 plots) after harvest of the cover crop. Soil water sampling is initiated and will continue until spring. Analyses on nitrate-N and K in the soil water are carried out. 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.

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 supply the necessary N for subsequent non-legume crops such as barley. Treatments without catch crop, with a ryegrass catch crop and with a clover grass catch crop are compared through three years. In the treatments without catch crop or with ryegrass catch crop pig slurry containing 64 kg N ha^{-1} is added to the spring barley each year, whereas in the treatment with clover grass catch crop no slurry is added, but K is applied in an amount corresponding to K in the slurry. Suction cups (3 per plot x 12 plots) were installed at 1 m depth in March. Soil water sampling, for nitrate-N analyses, has been carried out at 2-4 weeks intervals during spring and summer.

Screening of catch crops.
After application of 64 kg N ha^{-1} in pig slurry the barley crop was well established in a uniform seedbed with little weed infestation. The barley yields were uniform, however, a significant competition from the Persian clover in treatment 5 resulted in lower yield compared with the other treatments.

WP8 Very deep-rooted crops and catch crops in the crop rotation, N dynamics and modelling
Two replicates of the experiment on the effect of very deep-rooted crops in cropping sequences has been started, one with catch crops in the autumn of 2000 and vegetable crops in 2001, and the other with catch crops in 2001. Root growth have been measured on the catch crops in the two autumns and on the vegetable crops this year, and soil samples taken to 2.5 m depth in November 2000 and in May 2001 have been analysed for N_{min}. The results of these measurements show that very different root growth of catch crops and vegetable crops and that very different N_{min} profiles have been achieved. Both the fodder radish catch crop and the white cabbage crop have obtained rooting depths of more than 200 cm, confirming that they are very deep-rooted. Anyhow, it is too early to draw any conclusions about the results of this experiment.
During the first year of experiments with alternative deep-rooted catch crops for undersowing, 13 species were compared. With 5 of these species root growth was measured with the minirhizotron method, and N_{min} tests were made on 11, excluding two which was not successfully established. The minirhizotron measurements on undersown catch crops are difficult, as the roots of the barley main crop disappear quite slowly, and even in November it is not easy to distinguish roots of the growing catch crops from the roots of the barley crop which have been dead for more than three months. Therefore, the rooting of the catch crops was evaluated as the change in root intensity in various soil layers during the period from barley harvest until November.

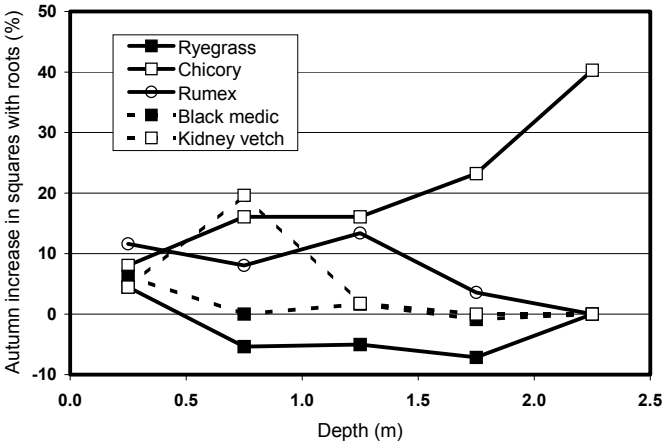

Figure 8.1. Root growth of undersown catch crops during the autumn after barley harvest. The measured data show the increase in % of root observation squares on the minirhizotrons with visible roots in the period from barley harvest until mid November.

The results show that with ryegrass and the two legumes, there were no significant increase in root numbers below 1.0 m during that period (fig. 8.1), indicating that these species had a root system that was distributed much as the root system of the barley. *Rumex acetoca* showed a significant root activity in the soil layer between 1.0 and 1.5 m, but little activity below 1.5 m. Chicory (*Chicorium intybus*) on the other hand showed a clear increase in root numbers in all soil layers between 0.5 and 2.5 , i.e. at least one m deeper than any of the other species.

The N_{min} measurements from 2000 did not give show very clear results. The amount of inorganic N was lowest under chicory in accordance with the root measurements, but generally the differences among species were non-consistent, and the soil depletion even in the upper soil layers were not as effective as we have normally found for this type of crops.

The growth season of 2001 has not ended, but the very preliminary root results obtained until now confirm the very deep root growth of chicory, and indicate that only a few of the other species we test may have significantly deeper rooting that ryegrass.

The experiment with undersown catch crops is used for studies in other parts of the VegCatch project, e.g. on S and K dynamics, on catch crop effects on soil mesofauna and on plant pathogenic nematodes. B.Sc. student Karsten Bach (KVL), is participating in the experiment and will make his B.Sc. thesis on root growth and soil N depletion by undersown catch crops.

Modelling work has been initiated in relation to a review paper, which we are currently writing, but not all relevant scenarios for this WP have yet been constructed. This is mainly due to problems employing a researcher full-time for a short period on this project. However, as Research Assistant Anders Pedersen is now employed on this and the BIOMOD project, the delay is not anticipated to disturb deliverables.

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. The catch crops from autumn 2000 showed a very wide range in chemical composition regarding S content and C/S ratio (Table 1).

Table 9.1: Composition of catch crops

Catch crop	S-content	C/S
Fodder radish	0.81	48
Winter rape	0.54	77
Chicory	0.43	99
Evening primrose	0.37	118
Parsnip	0.34	120
Ryegrass	0.36	122
Rumex	0.34	128
Bibernelle	0.28	161
Black medic	0.27	172
White clover	0.26	173
Kidney vetch	0.20	221
Lupin	0.17	265

In spring 2001 a pot experiment was established to determine the mineralisation of S from the different catch crops. Some initial results on grain yield only from this study indicate the availability of S in the catch crops is related to the C/S ratio of the material (Fig. 9.1). The C/S ratio explained about 60% 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. However, these results need to be confirmed evaluating the S-uptake in both grain and straw.

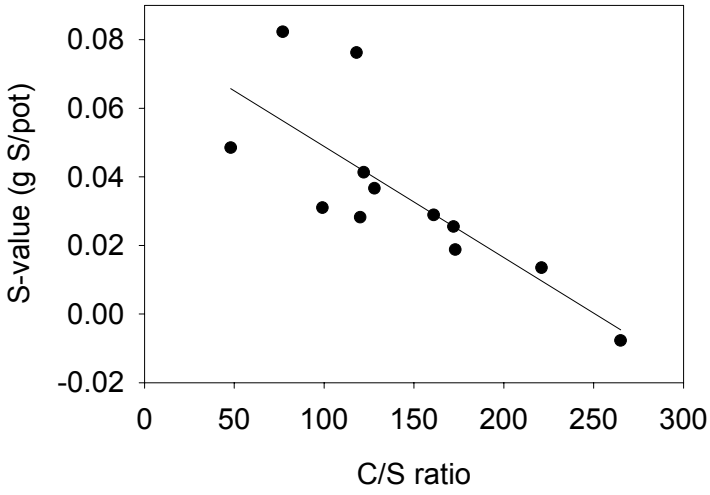

Figure 9.1: **Relationship between C/S ratio and S-value of catch crops**.

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

(To be completed for each work package)

** Deviations are to be further discussed at C3*

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		ongoing
2 To study rooting depth during growth and N dynamics for 6 vegetable crops		ongoing
3 To supply data on N root growth and N dynamics for modeling (WP8 and the Project BIOMOD)		just started
4 To test N effects of green manure crops incorporated in the late spring		ongoing, may be delayed*
Deliverables and milestones		
1 Papers on growth, root growth, and N dynamics of the three vegetable crops grown in 2000 and 2001.	2002	not started
2 Papers on growth, root growth, and N dynamics of the three vegetable crops grown in 2002 and 2003.	2004	not started
3 A paper on root growth of cabbage, leek and red beet from the cropping sequence exp. (see WP8)	2004	not started
4 A paper on legumes that are allowed to grow and fix N in the spring before vegetable crops	2003	not started

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	Extra work 2000,2001
2 Comparing levels of EPN on neighbouring farms with different growing systems	2000-2003	Ongoing
3 Screening of plant species for their value of supporting populations of EPN	2000-2003	Ongoing
4 Susceptibility of beneficial arthropods to EPN	2001-2002	Dealyed*
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	Dealyed*
3 Scientific paper on the ability of different catch crops to enhance and support populations of entomopathogenic nematodes.	2003	Not started
4 Scientific paper on results from project with susceptibility of non target arthropods Presentation of results at The Danish Plant Protection Conference	2003	Not started
5 Spring 2002, Selection of the most promising catch crops regarding their ability to enhance nematode populations.	2002	Not started

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		Ongoing
2 To study the significance of various pests, diseases and quality defects in vegetables grown in organic or conventional production systems		Ongoing
Deliverables and milestones		
1 An international scientific paper on the organic grown carrot, cauliflower and onion varieties	2004	Not started
2 An international scientific paper on differences between organic and conventional growing of onion, carrot and cauliflower	2004	Not started
3 A guideline for growers and advisors, describing the most important characteristics,	2003	Not Started
4 Preliminary publications, from the evaluation of carrot, cauliflower and onion varieties, every year.	2001-2004	Ongoing

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.		Ongoing
2 To quantify the influence of these catch crops on subsequent main crop yield and P uptake		Not started
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.		Ongoing
Deliverables and milestones		
1 Papers on the effects of undersown catch crops on P bioavailability for subsequent crops.	2003	Not Started
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		Not Started
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		Not Started
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	Not Started
2 Results from the first year field experiment has been obtained.	2003	Not Started
3 Results from the second year field experiment has been obtained. Paper on effect of autumn green manure crops on *P. brassicae*	2004	Not Started
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	Not Started

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.		Ongoing
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.		Ongoing
Deliverables and milestones		
1 Scientific paper on the effect of undersown catch crops in cereals on the soil fauna	2001	Not Started*
2 Scientific paper on the effect of deep-rooted catch crops on the soil fauna	2003	Not Started
3 Scientific paper on the effect of catch crops at different levels of nitrogen and potassium on the soil fauna.	2004	Not Started
4 Popular scientific paper on the results.	2003	Not Started

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		Ongoing
2 To test N supply from undersown legume catch crops for continious grain production		Ongoing
3 To identify legume- and non-legume catch crop species suitable for undersowing on coarse sandy soil.		Ongoing
4 To estimate the influence of catch crop rooting depth on cation leaching from the root zone on a sandy loam soil.		May be delayed*
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	Not Started
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	Not Started
3 Paper on the cation and anion balances as affected by different catch crop types on a clay soil	2004	Not Started
4 Papers in national agronomic magazines for information about the results	2003-4	Not Started

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		Ongoing
2 To obtain data on root growth and soil N dynamics for validation of model simulations of deep soil N dynamics		Ongoing
3 To identify plant species with very deep rooting which can be established as undersown catch crops in cereals.		Ongoing
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.		Ongoing
Deliverables and milestones		
1 Data from the cropping sequence experiment will be delivered for the BIOMOD project	2001, 2002 and 2003	Just started
2 A paper on the effects of crops with different rooting in cropping sequences on N dynamics.	2004	Not Started
3 A paper on the rooting depth, soil depletion, N uptake and release of the undersown catch crops.	2004	Not Started
4 A paper on the value of very deep-rooted crops and catch crops in the crop rotation.	2004	Not Started
5 A paper on the developed decision support system.	2003	Not Started
6 A decision support system on optimal use of catch crops	2003	Not Started
7 Early spring, 2002: Selection of deep-rooted catch crop species to be included in the last year of the cropping sequence experiment.	2002	✓ *

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*

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

Task		
1 To determine the ability of catch crops to reduce soil sulphate concentrations		Ongoing
2 To determine the ability of catch crops to make S available for the succeeding crop through mineralization.		Ongoing
Deliverables and milestones		
1 Paper on the effect of catch crops on sulphate leaching submitted to international refereed journal	2002	Not Started
2 Paper on the sulphur supplying capacity of catch crops to the succeeding crop submitted to international refereed journal	2002	Not Started
3 Paper to Danish farmers and advisors on the effect of catch crops on S utilisation	2002	Not Started

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

For the project as such, the progress is very much as planned. Though only a small part of the results are obtained by now, they have generally shown interesting results. The first publications are starting to appear, and the experiments have been presented at open house days etc. Two students from KVL now are working on the project.

The need for overall co-ordination of the activities in all WPs is limited, as they deal with very different subjects, but a number of interactions between individual WPs working on various aspects of the same experiments are going well.

WP1 Nitrogen relationships of vegetable crops
Data from two different experiments have shown very different root growth of vegetable crops, from only 50 cm for leek and celery, maybe 75 cm for sweet corn, and 150 cm for red beet to more than 240 cm for white cabbage. The data also show interactions with management practices such as incorporation time of a green manure crop. With such large differences, the preliminary results confirm the need to know more about root growth when planning organic crop rotations.

The experiment on spring growing green manure has partly failed this year due to the winter conditions and an experimental error. Based on the limited results from 2001 and the results we will obtain in 2002 we will decide whether to repeat parts of the experiment in 2003.

WP2 Entomopathogenic nematodes in organic cropping systems
Few results are ready yet, apart from the measurements on an organic farm and neighbouring conventional farms. In this case the number of nematodes was much higher at the organic farm, and if that is a general trend, it shows that the nematodes may be important especially on organic farms.
Some delay in the work occurs, as the initial level of nematodes in the soil in Årslev was found to be low, and it has been necessary to introduce nematodes to the soil to be able to study their performance and effect.

WP3 Varieties, growing stability, disease resistance and quality
Also in this WP few results are ready yet. Anyhow, the experiments have shown that we can grow organic carrots with good success, and in the first year the saleable production was substantially higher than in conventional production as much less was discarded due to the disease “cavity spot”. Onions on the other hand produced a substantially smaller yield in organic production. It has been a positive result that we have been able to cauliflower successfully, as it is normally considered to be very difficult to grow organically.

The only deviation from the original plan is that most of the activities on carrots have been moved to commercial farms in Jutland. This has been done as the soil in Årslev is not well suited for carrot production, and Danish commercial growers practically never produce them on sandy loam soils at the Årslev soil.

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

The experiments have started, but no results have been obtained yet. Unfortunately the catch crops were not too well established this year, but it is too early to judge whether this will have consequences for the work in the WP.

WP5 Influence of autumn green manure crops on club root
Has not started yet.

WP6 The effect of catch crops on soil mesofauna and earthworms
The results clearly show that growing catch crops strongly increase the numbers of soil animals. The effects on Collembola and earthworms show very strong increases in the range from a factor of 2 to a factor of 10. The results on mites are less clear. generally, all the catch crops had these effects, though it seemed that white clover may have a better effect than the others, maybe due to larger amounts of nutrient rich plant material added to the soil fauna. Whether a higher biodiversity was also found has not yea been analysed. As there are reason to believe that a soil with high biological activity is an advantage in organic production, and positive effects of earthworms have clearly been shown, these results demonstrate another strongly positive effect of catch corps apart from the N effects more frequently studied.

WP7 The effect of catch crops on N and K leaching and crop production on coarse sandy soils
The experiments have been started, but no results obtained yet. The plan to study effects of catch crops on cation concentration in the soil water (task 4) may be postponed or changed. Other work has questioned whether the method of extracting soil water by centrifugation will be suited for this purpose. Possibilities to study this question by other methods will be discussed at our project meeting this winter.

WP8 Very deep-rooted crops and catch crops in the crop rotation, N dynamics and modelling
The data indicate that catch crops for undersowing with clearly deeper root systems than grass may be found. Though it is indicated that several species may have deeper roots, only chicory seems to have a root growth approaching what we have found on fodder radish. The data are though not conclusive yet. Other interesting species may be identified, and the results on depletion of soil N in the first year was not clear.

Data from the cropping sequence experiment demonstrate that species with very large differences in root growth can be found, and that the species we have chosen have shallow, medium, or deep rooting as intended. This should allow us to study the effects on deeper soil layers we wanted to study.
The only deviation from the original plan within this WP is that we have already chosen chicory as the deep-rooted catch crop to be used in the third year of the cropping sequences where it will be compared with treatments with ryegrass and with no catch crop. This decision has been taken early, as the difference between chicory and any other catch crop were so clear in the results of 2000 and a similar result is indicated by the preliminary results from 2001.

WP9 The effect of catch crops on sulphate leaching and availability of S for the succeeding crop
Soil data to elucidate the ability of the different catch crops to prevent S leaching have not been analysed yet, but analysis of plant S uptake show substantial differences in uptake and very large differences in S concentration or C/S ratio in the plant material among catch crops. Preliminary results from studies of the effect of these catch crops on S supply for a succeeding crop indicate large differences which are clearly related to C/S ratio. Together with results obtained in a previous FØJO project, this indicates that catch crops could become an important tool in handling S deficiency in organic farming. The differences among species are large, with crucifer species having very low C/S ratios, and legumes the highest. Whether this could have negative effects for the use of legume catch crops on soils prone to S deficiency cannot be concluded from these results.

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

WP1 Nitrogen relationships of vegetable crops
There are no changes in the original plans, as the experiments are going well, apart from some problems with the experiment on spring growing green manure. In the experiment with rooting depth of vegetables, the field measurements on the first three species have just been finished. It is planned to measure root growth of potato, Chinese cabbage, and zucchini. They are chosen as potato are a very important vegetable crop, Chinese cabbage is also important and no root data and soil N depletion by this species seem to exist. Zucchini is chosen to represent a whole group of vegetable crop species where no reliable data for root growth and N dynamics can be found.
An M.Sc. thesis to be written by Julie Schou Christensen, is expected to be finished in the spring of 2002. Apart from this, there are no changes in the plans for publication.

WP2 Entomopathogenic nematodes in organic cropping systems
A number of experimental activities have been started as described in the original application and under point C1 above. The activities for the next year will be continuing and repeating these experiments. There are no changes in publication plans.

WP3 Varieties, growing stability, disease resistance and quality
Also in this WP the plan is to continue/repeat the experiments. The variety trials are planned to be repeated during four years, and the second year experiments are just about to be finished in the field, but will continue until next spring with studies of storability of the products. No changes in publication plans.

WP4 Catch crops as a tool for increasing P bioavailability on soils of low P status
The experiments have just been started. Measurements of the P mobilisation by the catch crops are to be made in a few weeks, and in the summer 2002 studies on the effect of the catch crops on P supply for the next main crop will be studied. A new catch crop trial will be initiated to repeat these studies in the autumn of 2002 and in the summer of 2003. No changes in publication plans.

WP5 Influence of autumn green manure crops on club root
The experiments will start during 2002 with pathogencity tests of *P. brassicae* against a range of brassica species, to try to find brassicas with low susceptibility, and to identify genotypes with different susceptibility levels suited for the catch crop field experiments which will then start in the late summer 2002. No changes in publication plans.

WP6 The effect of catch crops on soil mesofauna and earthworms
The first experiments, where the effect of undersown catch crops (see WP8) on density and dynamics of the soil fauna (Collembola, mites, and earthworms) is now finished. Preparation of the scientific paper on these results is about to start. It is not likely to be finished within 2001 as scheduled, but only a small delay is expected, with a submission during early 2002. Sampling in Årlsev for the studies of the effect of deep-rooted catch crops on the soil fauna also in deeper soil layers will start now (Nov. 2001) and continue with sampling in the early summer 2002. Sampling in Jyndevad (WP7) for studies of the effects of catch crops/N levels/K levels on a sandy soil on soil fauna will start in the late season of 2002. Apart from the above-mentioned delay of the paper on the first experiment, there are no changes in publication plans.

WP7 The effect of catch crops on N and K leaching and crop production on coarse sandy soils
Field experiments with catch crops have been started during 2001, and the effect of the catch crops on leaching and supply of N and K will be studied during the winter season and during next summer. One of the experiments will be continued until 2004, while new repetitions of the others will be started again in 2002 for measurement of effects on subsequent crops in 2003. Regarding task 4 the soil samples will be frozen and stored, while alternative methods for soil water extraction are considered. No changes in publication plans.

WP8 Very deep-rooted crops and catch crops in the crop rotation, N dynamics and modelling
The experiments on cropping sequences with very deep-rooted plants have been started, one to run from 2000 to 2002 and one has been started in the autumn of 2001 and will continue until 2003. These experiments will continue as planned. Regarding the screening for deep-rooted catch crops for undersowing, we will try to select some of the most promising species for the studies in 2002 and 2003. In the original plans Nmin samples were to be taken in all crops, but minirhizotrons only to be used in selected crops. We consider reducing the number of species studied a little, but then using both Nmin and minirhizotrons in all of them.

A B.Sc. thesis is expected to be published from the studies on deep-rooted undersown catch crops during 2002, apart from this, there is no changes in the publication plans.

WP9 The effect of catch crops on sulphate leaching and availability of S for the succeeding crop
In autumn 2001 the effect of catch crops on the coarse sandy soil at Jyndevad experimental station will be evaluated, including sulphate leaching using ceramic suction cups and uptake in catch crops (see WP7 for description of experiment). Catch crops will be collected for mineralisation studies in pots to be carried out the growth season of 2002. No changes in publication plans.

E. Project publications

1. Articles in international, scientific journals with review procedures
2. Presentations 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

F. Scientific education (ph.d. and post doc.), including visiting scientists and visits abroad

In connection with COST action 829 ”Fundamental, Agronomical and Environmental Aspects of Sulfur Nutrition and Assimilation in Plants” Jørgen Eriksen visited the University of Oulu, Finland on September 7-8, 2001.

Julie Schou Christensen (KVL) is working in WP1 and is writing her M.Sc. thesis on root growth of vegetable crops.

Carsten Bach (KVL) is working in WP8 and is writing his B.Sc. thesis on root growth and soil N depletion of undersown catch crops.

G. National and international co-operation

FØJO-project OrcTom, there will be co-operation with the work packages of this project dealing with root growth of greenhouse tomatoes vegetable crops and with the value of green manure crops for nutrition of greenhouse vegetable crops.

SJVF-project: Optagelse af kvælstof i dybe rødder – nøglen til reduktion af kvælstofudvaskningen fra jordbruget (Uptake of nitrogen by deep roots – the key to reducing nitrogen leaching losses from agriculture): 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.

FØJO-project BioMod, 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).

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 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.

H. Possible elaboration of project and achieved results

Though several results have by now been obtained, it is too early to draw any firm conclusions and thus too early to plan new activities based on the results.

However, many of the aspects removed during the application phase of the project due to the limitations set by the funding would still be worth including in the project. One of these, including teflon cups for soil water sampling at various soil depths of the experiments with deep rooting plant species would be a very valuable addition to the current activities. The results obtained could 1) Clearly improve the information about the effect of the deep rooted crops on N leaching, 2) be used to test the validity of the usual practice of calculating N leaching loss based on data from ceramic cups placed at a depth of 100 cm, and 3) be used to give new information on the effects of catch crops on leaching loss of other plant nutrients, e.g. S and K.