Application for the project:

Organic production of cucumber and tomato grown in composted plant material from field crops

I.1 Organic production of cucumber and tomato grown in composted plant material from field crops

Acronym: ORCTOM

Date: October 4, 2002

1. Summary

The overall aim of the project is to develop production systems for organically grown glasshouse vegetables of good quality, utilising cheap, easily available growth substrates. The substrates should, first of all, release sufficient nutrients for the plants through the cropping period, but large excesses of nutrients should be avoided. Furthermore, the environment should not be contaminated with excesses of the supplied nutrients.

In greenhouse vegetable production, large amounts of plant nutrients are needed, and e.g. a tomato crop will need approximately 20 times as much nitrogen as most field crops. In organic production this leads to two main problems. Plant nutrients is a limited resource in organic crop production, and it can be difficult to acquire the large amounts needed from organic sources. In organic production where the crops are grown directly in the soil, addition of such large amounts of manure or compost to the soil can lead to serious risk of nitrogen leaching and other losses of plant nutrients to the environment.

It is generally assumed that organically produced vegetables is of better quality than conventional products, though such differences are not well documented. As plant nutrition cannot be controlled as precisely as in conventional production, temporal quality problems can occur due to excess, deficiency or imbalance between plant nutrients.

Thus, there are potential problems with nutrient losses and possibly quality, but we know little about how serious these problems are in the present organic vegetable production systems. Therefore the first goal of the project is to study the present systems used in organic greenhouse vegetable production, study nutrient balance, potential for nitrogen leaching loss and quality of the products.

The problems discussed, in combination with large investments for converting greenhouses from conventional to organic production and the risk for build up of soil diseases and pests in the greenhouse soil, has led to an interest in organic production where the plants are grown in compost in limited beds, i.e. without contact to the soil in the greenhouse. Using this method, the crops can be grown in organically produced composts, but it is possible to combine this with some of the advantages from the conventional production methods. Leaching losses can be prevented as drainage water can be collected, and problems with nematodes and soil borne diseases are prevented as the compost is changed for each crop. At the same time, conversion of conventional greenhouses to organic production will be cheaper, as much less changes will be needed in the greenhouse.

However, growing the crops in limited beds is seen by many as being in conflict with the basic ideas behind organic farming, and growing the plants directly in the soil also has advantages which will be lost by changing to growing the crops in limited beds. Soil is a very diverse growth medium, which will supply all nutrients and trace elements to the crop. Further, when the plants are grown in the soil, it will allow them to explore a large soil volume, and thus exploit the reserves of water and many nutrients within the rooting zone of the crop will be bigger than in limited beds.

The conclusion is, that important problems and advantages are found with either of the systems, and a solution could be to develop a system which combines the most important advantages of the two systems. In the project we want to compare these two systems with a intermediate system, where most of the compost is added to a limited bed, but where the plants are allowed to develop their root system both in the compost and in the surrounding soil. The amount of compost added directly to the soil can then be reduced to much lower levels and thereby the leaching risk will be strongly reduced, the drainage water

from the compost can be collected, and the compost will be changed before each crop, so at least in this part of the root zone of the crop it will not encounter soil-borne pests and diseases due to previous crops.

The objective of the project is to: 1) Study existing organic greenhouse vegetable production systems, e.g. nutrient balance, effects on soil organic matter and nitrogen leaching losses and on quality of the products, 2) Develop composts primarily based on clover-grass hay, straw and other plant materials which will be easy to obtain from organic farms, and 3) Develop and compare existing and alternative growing systems, study their effect on nutrient balance, leaching losses, crop production and quality. The results from the first part of the project will be used when deciding how much of the effort in the later part is to go into development of alternative systems, and how much is to be used for further development of the existing methods.

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3. Introduction

The demand for organic vegetable products is increasing fast, and often the demand is higher than the production. Organic tomato and cucumber are currently produced on an area not larger than 3 to 4 ha in Denmark (pers. communication Jytte Bak, Gartneriet Markhaven), compared to the 70 to 80 ha of conventional production (pers. communication Søren Møller, DEG). Yields are normally lower in organic production (50-75%, but increasing) compared to conventional production, and total market share for organically grown tomato and cucumber are thereby in the range of 2-3%. Organic production of tomato and cucumber in our neighbouring countries are of comparable size.

The growth in production of organic greenhouse vegetables is limited by two main factors. One is that the demand for plant nutrients is very high, and as availability of plant nutrients is generally limited in organic crop production, it can be hard to acquire enough manure from sources accepted for organic production. Another main factor is that it is very difficult and expensive to convert existing greenhouse facilities to organic production, or to establish new greenhouses for organic production.

The demand for plant nutrients in organic greenhouse vegetable production is very high, e.g. more than 2000 kg N ha^{-1} is needed for a tomato crop, which is roughly 20 times the amount needed for many field crops. Obviously, the normal level of nitrogen mineralization from the soil will only supply a small part of this, and large amounts of nutrients must be added to the soil. It can be hard to find sources for such large amounts of manure, as manure is not in surplus in organic agriculture, and only few organic dairy farms are situated in the areas where most of the greenhouse production occurs. For the time being, the production can be based mainly on import of manure from conventional farms, but this is not in accordance with the basic ideas of organic production.

Handling so much nitrogen in the soil also leads to a risk of loosing nutrients to the environment; which has been a serious problem with conventional greenhouse vegetable production in the soil. In organic production the regulations limit the amount of plant nutrients which can be added, and it is attempted to reduce leaching loss of nutrients by avoiding excess irrigation. The conclusion is that we do not know the extent of the leaching problem from the present organic vegetable production in greenhouses, but it could be substantial. It is therefore important to get figures showing whether leaching loss of nitrogen from the present organic systems are at an acceptable low level or improvements or alternative systems are needed to deal with this problem.

Secondly, it is very expensive to convert existing greenhouses to organic production, as most of the equipment and structures in the greenhouses will have to be removed to establish a system where the crops are grown in the soil. The experience shows that it will take some years with organic production before the soil releases enough plant nutrients for successful crops. As it also takes two years before the products can be marketed as organic, the investment in converting a greenhouse to organic production will be followed by some years with low income, a situation which is strongly discouraging the conversion of conventional greenhouses to organic production.

The low yield in the first years are presumably due to too low nutrient release from the added organic manure, even though the total amount of nutrients added is sufficient for the crop. Only part of the nutrient content becomes available for the first crop, the rest of the nutrients are either not mineralised during the first year, or they are immobilised again in the soil. These nutrients can contribute to the nutrition of the subsequent crops. After some years, a higher mineralisation occurs from the soil, and together with the mineralization from the added compost this can supply enough nutrients for the plants, though the added amount are the same as in the first years.

A build up of soil borne diseases and nematodes in the soil can cause serious problems to greenhouse vegetable crops and weaken their root system (e.g. Gilreath et al., 1995; Duponnois et al., 1995; Bourne et al., 1996). Previously such problems were handled by frequently sterilising the soil with chemicals or steam. The present rules for organic production do not consider these problems, though the use of chemicals is obviously not allowed. Although steam sterilisation could become an accepted method in the regulations, it is expensive, and it uses a lot of energy and kills most of the living organisms in the soil, and does thus not seem to be in line with the ideas of organic farming. In outdoor vegetable production, crop rotation and cover crops are used to handle these problems. These methods are not realistic in organic greenhouse production as there are few available crops to rotate, and since greenhouses are very expensive installations it is not realistic to use fallow or low value break crops. Thus, other methods are needed to control the problems, which can occur due to intensive monoculture in greenhouses.

Together these considerations has led to an interest in systems where organic greenhouse vegetables are grown in organic growing media in limited beds without contact to the soil in the greenhouse. Currently, such systems are tested in practical production in Denmark, and e.g. in Finland the production is generally based on growing in peat in limited beds.

Growing the crops in compost, which is not in contact with the soil, could solve some of the potential problems with the current methods where the plants are grown directly in the soil:

1) The drainage water can be collected to prevent leaching losses.
2) It could allow a larger and more controlled utilisation of the nutrients in the compost.
3) The compost can be recycled to the fields after use this would allow a better nutrient balance of the production.
4) Starting each crop in fresh compost will prevent build up of nematodes or other soil pests or diseases due to continuos production of the same crop.
5) Conventional greenhouses could be converted to organic production with much less investments.

On the other hand, many people see methods where the crops are grown in limited beds as in conflict with the principles of organic farming, and growing the plants in the soil has several advantages. The large rooting volume, which the plants can develop in the soil, and the diverse soil medium, which is a good buffer for water and many plant nutrients can make it a more stable and reliable growing medium than compost in limited beds.

Thus, growing the crops directly in the soil also has important advantages, but we should make sure, that the systems used will also be environmentally acceptable. Therefore, we need to study whether the present organic greenhouse vegetable production methods are able to handle the large amounts of plant nutrients without unacceptable environmental effects. There is a need to work with further development of the present growing systems, or development of new growing systems where the large amounts of plant nutrients can be handled with less leaching losses is needed.

Intermediate systems, where most of the compost is added to limited beds, but where the crop roots are allowed to develop both into the compost in the limited beds, and also into the soil below, could potentially combine many of the advantages of the two systems. Further they could make it possible to achieve a good yield also in the first years after converting to organic production, to enhance the possibilities to establish new organic production.

To make this a realistic method for large-scale organic greenhouse vegetable production, the growing medium must be easily available from acceptable organic sources and relatively cheap. Cereal straw has previously been used as a growing substrate for cucumbers (Amsen, 1974) and has been tested for tomatoes with good results (Allen, 1963).

Cereal straw is very poor in plant nutrients, and in previous cropping in straw, all necessary nutrients have been added as chemical fertilisers. Animal manure, slurry or liquid manure is a scarce resource in organic farming. Therefore, using plant material with higher nutrient content than straw, e.g. by making composts of a mixture of cereal straw and legume plant material, could be an attractive method for supplying the vegetables with all or most of their nutrient demand.

In the areas, where most greenhouses in Denmark are situated there is only little organic animal production. On the other hand, organic farms with few or no animals will often grow clover grass leys as green manures, and if they can harvest and sell some of their green manure crops, this will be an economically attractive possibility on such farms. Mixtures of cereal straw and clovergrass hay will thus be a growth substrate, which can be available from local organic farms, even if only stock-less farms are present in the area. After use, the residues of the growth medium and the crop residues from the greenhouse vegetables can be recycled to the farms for soil improvement there.

Composts should release sufficient amounts of many plant nutrients, and they should release that at the right time and balance between the nutrients. Timing of nutrient release and balance between important nutrients can be adjusted by selecting plant species for the compost, age of clovergrass at cutting and relative amount of the different ingredients. Further, the compost can be optimised by adding other nutrient sources, e.g. animal urine, vinasse, limestone, or municipal compost. Such additions can be used to improve the compost itself, or can be added directly to the crop as top-dressing at stages of the production where specific plant nutrients can become limiting.

Tomatoes grown in Denmark are primarily used fresh in e.g. salads. So the most important quality characteristics are taste (aroma, sweetness, sourness), texture and keepability. When they occur, physiological disorders such as blossom end rot can be major quality problems. Consumers who buy organic tomatoes expect superior eating quality (Johansson et al. 1999), and if they experience clearly inferior taste or texture, this may influence them to avoid organic products later. So avoiding serious quality flaws is a major issue, while small differences in quality are not expected to affect the market value.

Quality differences among tomatoes tend to be smaller than for other fruits. However, both in experiments with tomatoes and other fruits, the highest yield and the best quality has often not been found in the same experimental treatment (e.g. Sangeeta et al. 1997). So it is not certain, that a cultivation method can be found that will optimise both yield and quality, but in order to chose a compromise leading to good yield and quality at the same time, the differences must be known and taken into account.

While quality of cucumber is of course also an important issue, there does not seem to be any clear-cut relationship between strong flavour and good taste, making it more difficult to define good sensory quality. So in this species the quality evaluation will primarily be as part of the yield evaluation, as weight distribution and visual evaluation as percentage grade 1 product.

Based on this it is the aim of the project to develop improved cropping systems. We will test the current systems, compare them to alternative systems and monitor the release of nutrients and the effect on plant growth, yield and quality. The initial work will be aimed at determining which improvements are needed. Based on this, we will begin work to optimise the growing method. By the end of the project it is the aim to be able to recommend a system for growing organic crops of cucumber and tomato, where good yield and quality can be obtained, where the risks of nutrient leaching is minimised, and where the production is based on easily available growth substrates of organic origin.

4. State of the art

The nutrient demand of tomatoes or cucumbers grown in greenhouses is very high, compared to other crops. The daily requirement of a typical Danish conventionally grown cucumber crop, in mg $plant^{-1}$ day^{-1}, is 380 N, 80 P, 550 K, 225 Ca, 50 Mg, 60 S plus trace elements (Willumsen, 1996). The requirement of a tomato plant is almost the same (Alarcón et al., 1997). With two cucumber plants per m^2, their requirement in kg per ha is about 900 N, 200 P, 1300 K, 550 Ca, 120 Mg, 150 S plus trace elements for a cropping period of 4 months, the requirements of tomatoes is approximately twice as large as they are grown for a longer season. The soil and manures used should be able to release this amount of nutrients for the crops.

The release and availability of nutrients, root growth dynamics and nutrient uptake will effect plant growth and yield. The distance is very short between being able to meet the nutrient demands of the vegetable crop and having temporary levels of excessive nutrient availability and thereby a risk of nutrient leaching losses to the environment, especially where nutrient availability depends on nutrient mineralisation of decomposing plant material. Tomato plants grown in the soil in greenhouses are likely to be deep-rooted, in the field rooting depths of approximately 1.0 m have been found (Hösslin, 1954; Qasem, 1993), but tomatoes grown in greenhouses are likely to have significantly deeper rooting than that. Development of rooting depth seem to be related to temperature sum from establishment (Thorup-Kristensen, 1998, 2000) and as tomatoes in the greenhouse have a long growing season at high temperature they could have much deeper rooting than found in the field.

With such deep rooting, temporary leaching of nutrients from the topsoil layers is not necessarily a problem, as the nutrients can be absorbed by roots in deeper soil layers at a later stage, rather than being lost to the environment. It is not always found though, that a crop is able to deplete its root zone of nitrogen (Robinson et al., 1994; Thorup-Kristensen and Sørensen, 1999; Thorup-Kristensen and Van den Boogaard, 1999). If the crop is well supplied with nitrogen, the depletion of the deeper soil layers is less efficient, and Robinson et al. (1994) showed that plants with low N supply could effectively deplete N added to a soil layer within a week, whereas well supplied plants could not even though they had much higher root length density in the same soil layer.

Therefore, as the amount of available N in the soil is kept high enough to allow a very fast N uptake by the tomato crop, there is a risk that the deeper parts of the root system will not be able to deplete N which has been leached to deeper soil layers, as we have previously found with carrots (Thorup-Kristensen and Van den Boogaard, 1999). Allowing the tomatoes to be slightly N starved during the later part of growth could be one method to make them deplete deeper soil layers of their N content, and could have a profound effect on leaching losses. On the other hand, a soil where large amounts of organic matter have been added for years will have a very high mineralisation potential, and it is thus not certain, that it is possible to reduce the N supply to the plants enough at this late stage of growth to obtain the desired N depletion of the subsoil.

One solution could be to develop cropping systems where most of the compost is added to limited beds, but where the plants are allowed to grow their root system both into to compost in the limited bed, and into the soil below. In such a system, the risk for downwards leaching of N will be lower and the mineralisation rate in the soil will not become as high, thus it will be easier to make the crop deplete deeper soil layers at the end of the growing period.

A number of experiments have been made where the plants are grown in split-root systems (e.g. (Agrell et al. 1994; Gersani and Sachs, 1992; Minchin et al. 1994). In most of these experiments the split-root system was studied as part of more basic studies about plant nutrition and root growth. Still, the results have shown that plants are adapted to develop their root system in a diverse environment, where different parts of the root system have very different growth conditions, soil types, nutrient availablitiy etc.

Greenhouse crops can also be grown in limited beds without contact to the soil. In conventional production the plants are grown in inactive media, but growing the plants in compost, peat, or soil in limited beds is also possible. By growing in limited beds, problems with leaching loss or soil borne diseases can be controlled, though the advantages of the large buffer capacity of the soil for water and many plant nutrients is lost.

A number of studies of different soil-less substrates have been made (Lamanna and D'Angelo, 1991; Gouin, 1998) using compost from different sources. Many of the problems that have been identified have been related to salt problems, structural problems and water capacity problems, all factors that are very critical in an efficient production (Weinhold and Roeben, 1997). An emphasis on obtaining high quality uniform soil-less substrates is essential to enhance the organic production, but this needs to be closely co-ordinated with water and fertilisation techniques, since the organic fertilisers are releasing their nutrients over a longer period, compared to the immediate availability of chemical fertilisers (Berner et al., 1996).

The requirements for a good growth substrate is an air capacity above 15%, a water holding capacity above 60%, a temperature less than 30°C and good stability so that the substrate retains a reasonable volume for root growth (Gislerød, 1978). The quantity of mineralised nutrients being released from the composted growing medium should be of this magnitude for a 4 months period if no other fertilisers are applied. The nutrient requirements might by proper management be lower in a organically grown production.

The composts could be composed of mixtures of wheat straw as a structural component, and clover grass or pure clover hay as a main nutrient source. These two materials have very different nutrient contents. Wheat straw will typically contain approx. 5 g N, 1 g P, 10 g K, 3 g Ca, 1 g Mg and 1.5 g S pr kg dry matter (Olesen and Vester, 1995; Strudsholm *et al.* 1997). Clover grass will contain about 25 g N, 4 g P, 30 g K, 10 g Ca 2 g Mg and 3 g S pr kg dry matter (Olesen and Vester, 1995; Strudsholm *et al.* 1997). These concentrations can be varied by selecting pure clover or clover grass mixtures and by selecting the growth stage for harvesting; earlier harvesting will lead to hay with higher nutrient concentration and faster decomposition and nutrient release. Other materials could be added to control the nutrient concentration, e.g. brassica crop residues with a high S and Ca content, limestone to supply Ca and Mg, vinasse to supply K etc.

Experiments where clover grass mulches have been used as the nutrient source for organic greenhouse tomato production (Gäredal & Lundegårdh 1997, 1998) have confirmed that this could release enough nutrients for a tomato crop of longer duration. Yield approached 21 kg per m^2 when the crop was mulched with clover grass. This is a rather low yield, but the amount of N added with the clover grass was only in the order of 500 kg N ha^{-1}, which will be much too little. By adding more realistic amounts, it is therefore likely that substantially higher yields could be obtained with this source of nutrients.

During the composting the plant material is broken down by the activity of fungi and bacteria. Within three weeks the temperature may drop to about 30°C but subsequent re-wettings and turnings will raise the temperature new but lower peaks. The composting process will lead to O_2 absorbtion and release of CO_2, NH_4 and other nutrients. Addition of a nitrogen source to the composting material can be used to increase the speed of the composting process, or addition of a carbon rich material as straw to delay mineralisation if that is needed. Plant nutrient mineralisation will occur both during the composting process and afterwards when the compost has been added to the soil or growing beds.

Nitrogen rich plant materials as clover or other legumes can release 50% or more of their initial N content within a few months of decomposition (Wivstad, 1999; Thorup-Kristensen, 1994), due to their low C/N ratio. Normally, much of this N release occurs during the first few weeks of decomposition, i.e. before the cucumber or tomato crops need it. Mixing clover with cereal straw, which has a much higher C/N ratio, will lead to immobilisation of some of the N released from the clover residues during early turnover, even though the decomposition of the straw will be relatively slow. The N which is released from the clover and subsequently immobilised due to microbial growth on the N poor straw, can be released again later at a time when it is more needed by the crops (Båth, submitted). An optimal compost should contain enough N rich materials to supply N for the crops, but also enough available C for the microorganisms to prevent a too high net N mineralisation during the early phases of decomposition.

P and S are build into organic compounds in the plants similarly to N, and must be mineralised before they become available to other plants. Previous results have shown that both P and S can be readily mineralised, the mineralisation rate depending on various factors (Dalal, 1979; Till and Blair, 1978; Enwezor, 1976, Eriksen et al., 1999) where as C/P ratio and C/S ratio seem to be of major importance as the C/N ratio for N mineralisation. On the other hand, K, Ca and Mg is present as ions in the plant material, and do not need mineralisation to become available. Still, Ca and Mg are integrated in e.g. structural material in the plant cell walls, and their availability is thus also dependent on decomposition of the plant material. K is not bound in the plant material, and can be regarded as immediately available for other plants (Christensen, 1985). Considering the amounts of various nutrients available in the composted materials, this could lead to excess availability of K compared to other nutrients, and an imbalance between K supply and Ca and Mg supply. Such an imbalance can lead to quality defects (Willumsen et al., 1996), thus addition of lime to secure the supply of Ca and Mg relative to K could be necessary.

If grown without soil contact, the straw and clover material must also secure the supply of micro nutrients for the vegetable crops. The ability of the growth medium to do this, will depend not only on the total content and release of these nutrients, but at least for some nutrients as Mn and Fe it will also depend on pH and redox conditions within the growing medium.

Straw bales were widely used in conventional production of cucumber 25-35 years ago (Jensen, 1964; Raether, 1976), before the introduction of mineral wool. They have also been tried in tomato crops (Allen, 1963; Amsen, 1974). Presently, growing systems where cucumber crops are grown in limited beds containing compost based on plant materials are tested in Denmark, and the results of (Christensen, 1999), show indicate that such systems can be developed.

Fluctuations in the availability of nutrients (especially ammonium, potassium and phosphorus) during the production period can be expected due to the composting processes (Jensen & Leth, 1998). The availability of specific nutrients will at times be very high and can depress plant growth and/or fruit quality. To avoid high concentrations of ammonium and other nutrient elements in the root environment a nutrient buffer can be incorporated into the medium, for instance clay minerals such as zeolite or glauconite. Clay minerals will bind nutrients during periods of high availability and extend the period of availability, thus improving the nutrient element composition in the growing media over time. In an experiment with roses grown in compost it was found that the potassium and phosphorus availability was extended over a longer period and the total plant uptake was increased when using a nutrient buffer in the growing media (Nielsen & Rasmussen, 2000). Total plants size was increased and quality was improved significantly.

Consumer related quality of tomatoes are a composite of the sensory quality and the nutrient value. The most importan nutrint is vitamin C, where a few tomatoes (100 g) will supply a fourth of the daily requirement (Saxholt et al. 2000). The primary factor influencing all aspects of tomato quality is cultivar (Johansson et al. 1999), but a number of studies have shown that the growth conditions can also be important, in particular under nutrient limiting conditions.

It is established that growth conditions resulting in slight water stress will increase both eating quality, vitamin content and the risk of blossom end rot (Petersen et al. 1998). To retain nutrients in the root zone irrigation must be limited, so adequate supply of Ca in the growth medium must be assured to prevent this disorder. Several studies comparing different cultivation systems have shown, that when the same (high) level of nutrients is supplied, the type of growth substrate has little or no effect on quality (Gysi et al. 1997, Auclair et al. 1995, Kuensch et al. 1994). However, in one study, using organic substrates with significant differences in nutrient availability, increasing nutrient supply resulted in lower quality, but higher yields (Haglund et al. 1997). Also in conventional cultivation, in a study where relatively low levels of macronutrients were included, optimum for fruit quality was found at lower levels than optimum for yield (Sangeeta et al. 1997). In contrast to relatively slight effects of macronutrients on quality, several studies show that some micronutrients, notably boron, must be supplied in a defined range of approximately 2-6 ppm, both lower and higher values can cause quality problems (Oyewole, & Aduayi 1992, Ankush et al. 1990, Cheng 1987). So when designing improvements in the cultivation system it is important to ensure that quality will be retained, and preferably improved, compared with the present situation.

Regarding the question of effects of micronutrients on quality, the hypothesis has been set forward that also minor trace elements are important for quality, specifically aroma formation, so if plants are grown without access to soil, the taste can be less aromatic due to deficiencies in trace elements. To the best of our knowledge, this hypothesis has not yet been tested scientifically. However, we participate in a recently completed experiment (not part of the application) where three cropping systems, including one using

Grodan blocks and one using standard conventional soil culture are compared in terms of sensory evaluation of fruit aroma and contents of trace elements. The results will be analysed to determine if significant correlation is found for these characteristics, so we will have new results on this topic soon, which will show whether this could be an important point.

In the above mentioned studies, sensory quality was generally evaluated using a taste panel, supported by measurements of soluble sugars and acids and in some cases instrumental measurements of texture. While sensory analysis is an efficient tool to compare treatments or cultivars within one experiment, objective (instrumental) measurements are necessary to compare across experiments, to determine how much the "standard" treatments vary among years or investigators (Duden 1987). The important taste component represented by the volatiles responsible for the specific tomato flavour has been measured in comparisons of cultivars (Baldwin et al. 1998, Krumbein & Auerswald 1998). But even though several studies showed differences in flavour, analyses of volatiles are until now not reported in comparisons of cultivation methods. It is to be expected that changes in aroma compound composition due to cropping systems will be systematic across cultivars, thus of more general interest than the cultivar-specific data.

It should be noted that for other berry and fruit species, e.g. grapes (for winemaking) and apples, the importance of growing conditions on eating quality and keepability, in particular detrimental effects of too high nutrient supply, is a major concern (Kipp 1992, Cline 1990). It has resulted in specific recommendations for production of high-quality products receiving better prices than the bulk commodity.

5. Objectives and expected achievements

The overall project aim is to promote organic production of greenhouse vegetables by developing a method where easily available growth substrates can be used for the production. We want to compose growing media, which can supply all or most of the necessary plant nutrients, and limit the need for supplementary fertilisation. On the other hand, large excesses of nutrients should be avoided as such excesses may depress plant growth and yield quality. And third, the environment should not be contaminated with excesses of the supplied nutrients. This will be done by the development of production systems and by identifying and analysing the main obstacles for the fertilisation both with respect to agronomic and ecological performance.

1. The proposal aims at the following main achievements: To describe the nutrient dynamics and nutrient use efficiency of the current production systems.
2. To develop a production system for selected greenhouse vegetables with optimized nutrient use efficiency and thereby reduce the risks of nutrient leaching. The production system will be based on the utilisation of cheap and locally available composted plant material from field crops.
3. To evaluate the quality of the greenhouse vegetables from contrasting cropping systems.

6. Description of work packages including methods

Table 1: Work package list

Work package No	Work package title	Responsible participant	Budget	Start	End	Deliverable No
1	The nutrient dynamics and nutrient use efficiency of the current production systems.	Kai Lønne Nielsen	0.85	2000	2002	
2	Development of plant based compost	Kai Lønne Nielsen	1.0	2001	2003	
3	Project co-ordination, development and comparison of production systems for tomatoes.	Kristian Thorup-Kristensen	2.05	2001	2004	
4	Quality evaluation of the greenhouse vegetables from contrasting cropping systems	Morten Nielsen	0.8	2002	2004	

Table 2: Description of work packages

WP1: The nutrient dynamics and nutrient use efficiency of the current production systems.

Workpackage number:	1
Start date or starting event:	June 2000
Responsible person:	Kai Nielsen
Contributing persons:	Kristian Thorup-Kristensen, Morten Nielsen, Anette Thybo
Person-months (scientific):	10.5

Objectives

The aim of WP1 is to monitor the current organic cropping systems for their effects on the soil, release and availability of nutrients, root growth dynamics, nutrient uptake efficiency and the effect on plant growth, yield and quality. Based on this information we will evaluate the need for cropping system improvements in order to improve quality and reduce the risk of environmental contamination with excesses of the supplied nutrients. The development of production systems and identification and analyses of the main obstacles for the fertilisation both with respect to agronomic and ecological performance will take place in WP2.

Description of work

Year 2000 Description of status of current organic cropping systems
By analysis of added manures and harvested fruits, we will calculate a gross nutrient balance for the major plant nutrient organic greenhouse vegetable crops, this work will continue in 2001. To study long term effects of organic growing practice on the soil, we will take samples of soil, which have been grown with organic greenhouse vegetable crops for few or many years. The soil will be analysed for organic matter content and other relevant parameters. Nitrogen mineralization potential of the soil will be measured by laboratory incubation studies.

We will monitor rooting depth as well as root density and the availability of nutrients at several soil depths intervals (down to 2.5 m), in order to evaluate how well the crop has been able to deplete the available resources in the soil, and how much is left which can potentially be lost by leaching.

At the end of the growing season a 2.5 m long soil auger will be inserted in the tomato plant row and in the interrow. Soil samples will be taken in five soil layers, of 0.5 m down to 2.5 m. Soil samples will be analysed for ammonium-N, nitrate-N, rooting depth and root density (root length per soil volume). Tomato fruit from existing organic and conventional cultivation trials will be evaluated for quality using sensory analysis and measurements of texture, soluble solids, organic acids and vitamin C. To assess the background variability due to cultivar and grower specific factors, the conventional samples will comprise 3 different cultivars, each supplied from 4 different growers. The cultivar used in the current organic cropping system is 'Aromata', which is also included among the 3 conventional ones, and it will be supplied from 6 different variants of the organic system.

Year 2001 Description of plant growth (root and shoot) and nutrient dynamics, throughout a growing season
Throughout a growing season plant growth will be monitored at regular intervals (plant height, stem diameter, flowering etc.). Samples of fruits and young leaves will be taken and analysed for content of nutrients, to follow the nutrient uptake pattern of the crop during the season. Soil samples will be taken at regular intervals, and analysed for availability of nitrogen.

Root development will be followed in minirhizotrons placed both beneath the crop row and in the soil between the crop rows extending to a depth of 2.5 m in the soil.

Deliverables

1) Two popular paper in growers journals (Økologisk Jordbrug, Gartnertidende or similar)
2) Presentation at growers and advisors meetings.

Milestones

1) Evaluation of nutrient availability with soil depth at the end of the growing season, ultimo 2000
2) Evaluation of the effect of organic cropping practice on organic matter content, nitrogen mineralization potential and other parameters of the soil, ultimo 2001.
3) Evaluation of relative importance of existing cultivation conditions on tomato fruit quality, ultimo 2000.
4) Evaluation of rooting density and depth potential for the tomato and cucumber crops, ultimo 2001
5) Evaluation of potential for nutrient leaching with current cropping systems, ultimo 2001.

WP2: Development of improved production systems for selected greenhouse vegetables with optimized nutrient use efficiency and reduced the risks of nutrient leaching.

Workpackage number:	2
Start date or starting event:	January 2001
Responsible person:	Kai Lønne Nielsen
Contributing persons:	
Person-months (scientific):	8.5

Objectives

1) To develop composts for organic production of greenhouse vegetables (cucumber and tomato) where the plants primarily receive their nutrients from composted plant material from field crops.
2) To test the compost as a nutrient source for cucumber crops, and based on the initial results make further improvements of the compost, and combinations with top-dressing treatments.

Description of work

Compost based mainly on cereal straw, clover grass hay and possibly other plant materials that will be available from organic farms will be produced. The composts will be tested as a nutrient source for cucumber crops, and based on the results, further improvements of the compost will be made.

Year 2001

Compost composition

The proportions of each plant material (wheat straw and clover grass hay and possibly others) to be part of composts will be calculated on the basis of the macro nutrient content of each material, primarily the C/N ratio. Based on information from the literature a one to one mixture of wheat straw and clover grass hay will have a C/N ratio between 25 and 30, which should allow relatively fast decomposition without releasing too much N during the early phase of turnover. In the first experiments we will test the effect of variable C/N ratio on the nutrient release of the compost.

Exp. 1.

The mixture will be shredded and composted in heaps for five weeks, and then moved to the greenhouse before planting of the crops. Media with different C/N ratios will be produced giving 3 types of compost media:

1) C/N=20 (approximately 80% clover/grass and 20% wheat straw)
2) C/N=25 (approximately 65% clover/grass and 35% wheat straw)
3) C/N=30 (approximately 50% clover/grass and 50% wheat straw)

Measurements of nutrient content, pH and EC before planting.

Prior to the experiment the nutrient content of the wheat straw and clover grass components will be measured. Before planting of the cucumbers, the content of plant available nutrients in the compost or bales will be measured as well as measurements of electrical conductivity and pH of the media. Relatively large amounts of phosphorus, sulphur and calcium can also be immobilised for a period but will become available again for the plants (Bjerggård & Hansen, 1983). After the composting process in heaps have come to an end (temperature stable around 30 °C and volume constant), the compost will be transported to the greenhouse.

During 2001 initial small scale experiments will be made to test the effect of the different compost media on crop growth. Further, initial tests will be made on developing a system where tomato roots can develop both into a limited bed with compost and into the surrounding soil.

Year 2002

A first "field trial" with cucumber grown with different compost compositions is planned for a 4-month period, from January to April, in year 2002. The growth (top and root), yield, nutrient uptake and distribution will be measured during the experiment. Plant analysis for mineral nutrient content, both macronutrients, and at selected dates a larger number of micronutrients.

I.1 *Organic production of cucumber and tomato grown in composted plant material from field crops*

This experiment will be carried out in a 200 m² glasshouse compartment with automatic climate control and frequent monitoring of the CO_2 concentration of the glasshouse atmosphere. It will be possible to compare six treatments in each experiment by means of a complete block design to minimise positional effects within the glasshouse compartment. All treatments will be replicated three times. Equipment for recirculation of the drained solution will be established for each replicate. The glasshouse climate and the CO_2 concentration of the glasshouse atmosphere will be monitored at short intervals.

Year 2003
In the early spring nn experiment with different compost media for cucumber production will be made in Årslev. In the experiment we will try to optimise the compost composition further, based on the experiences from the experiment in the spring of 2002. If necessary, this will also allow time to make a third experiment with compost types for cucumbers later in 2003 or in the early spring of 2004.

Deliverables

1) At least 2 popular papers in growers journals (Økologisk Jordbrug, Gartnertidende or similar) on the results of specific experiments and on final conclusions of the experiments
2) Scientific paper on the effect of the effect of different compost compositions on growth, yield and nutrient uptake by cucumber.
3) Presentation at scientific meeting and scientific paper on the significance of compost mixture and supplemental fertilisation for growth and temporal nutrient uptake of cucumber.
4) Presentation at growers and advisors meetings

Milestones

1) Selection of the most suitable composition of field crop plant material for further work, summer 2002
2) Determining composts to be used in WP3, ultimo 2001

WP3: Development of improved production systems for selected greenhouse vegetables with optimized nutrient use efficiency and reduced the risks of nutrient leaching.

Workpackage number:	3
Start date or starting event:	January 2001
Responsible person:	Kristian Thorup-Kristensen
Contributing persons:	Kai Lønne Nielsen
Person-months (scientific):	15

Objectives

1) To co-ordinate the project. This includes securing the co-ordination between the activities in the three work packages, follow up on the progress of each work package, arranging internal project meetings and organising the preparation of status reports. It is also an objective to secure communication with an associated growers group, secure that the progress and results from the projects are presented to growers, advisors, and others at meetings, in articles, on a project homepage and in open house arrangements.
2) To develop an "intermediate" growing system where most of the compost is added to limited beds, but where the plants are also allowed to grow their roots into the soil. We will work on optimising plant nutrition both in systems where the plants are grown in the soil, and in the intermediate system.
3) To compare the intermediate growing system with systems where the crops are grown in the soil and systems where the crops are grown in limited beds. We will test effects on yield, fruit quality, nutrient balance and dynamics and potential leaching losses.
4) The final goal is to be able to recommend a system for growing high quality organic crops of cucumber and tomato, using easily available growth substrates and only limited amounts of additional nutrients, and a system where the risks of nutrient leaching is minimised.

Description of work

The work in WP3 will depend on the results of WP1. We will compare alternative cropping systems and we will work on optimizing cropping systems. Which cropping system we will concentrate on in WP3 depends on the results of WP1, and how we will try to optimise the cropping system depends on the problems we identify.

'The hypothesis is: it is possible develop a growing system, where the plants are able to grow their root system both into a limited bed containing most of the added compost, and into the soil below, which will combine most of the advantages of growing either directly in the soil or growing in limited beds.

Year 2001

Initial work to develop and design an intermediate system, where the plant roots can spread effectively into the soil while most of the compost is kept within a limited bed.

Year 2002

An experiment will be set up to compare three different growing systems: 1) Gowing in the soil 2) growing in limited beds and 3) growing in an intermediate system. Crop growth, macro- and micronutrient uptake, yield and quality (WP4) will be measured during growth. The ability of the tomato roots in the intermediate system to grow and spread in the soil will be measured, and compared to soil grown crops. Nutrient balance of the different systems will be calculated, and nutrient content in the compost after harvest in the systems with compost in limited beds will be measured, and analysis will be made of drainage water from the limited beds. The amount and depth distribution of the available nitrogen left in the soil at harvest will be compared in the systems where plant roots are growing in the soil. This experiment will preferably be made in an existing greenhouse with organic vegetable production, as the soil history may be very important for the results.

Year 2003

An experiment where tomatoes are grown either directly in the soil or in an intermediate system will be made. Based on the experience from 2002, alternative treatments of the two systems will be tested, trying to optimise yield and quality and to minimise nutrient losses to the environment. Results from the previous years will determine whether the emphasis at this point is mainly on growing directly in the soil, growing in the intermediate system or on both.

Deliverables

1) Project homepage
2) Two popular papers on the testing and comparison of cropping systems
3) Scientific paper on the comparison of tomato growth in soil, limited beds, and the intermediate system.
4) Scientific paper on root growth and soil nutrient depletion of tomatoes.
5) Presentation at scientific meetings.
6) Presentation at growers and advisors meetings.

Milestones

The milestones for WP1 is also valid for WP3 as these decisions will be taken on the basis of combined results from the two work packages. Further milestones are

1) Selection of the most suitable composition of field crop plant material for further work, summer 2002
2) Determining treatments to be used for the tomato experiment in 2002, ultimo 2001
3) Determining whether growing directly in the soil or growing in the intermediate system should have first priority in optimisation of the growing methods, ultimo 2002

WP4: Quality evaluation of the greenhouse vegetables from contrasting cropping systems.

Workpackage number:	3
Start date or starting event:	April 2001
Responsible person:	Morten Nielsen
Contributing persons:	Anette Thybo, Merete Hansen
Person-months (scientific):	8.5

Objectives

- To determine which of the compared cropping systems optimise sensoric and nutritional quality of tomatoes.
- To determine how relevant nutrient imbalances influence taste and other quality aspects, and thus to what extent special precautions should be taken to avoid certain deficiencies with particular effect on quality.
- To determine relevant objective quality characteristics of tomatoes grown in the compared cropping systems, in order ensure that the quality will be at least as good as in conventional systems.

Description of work

The work will comprise measurement of quality of fruit from WP2 using a combination of sensory and instrumental methods

The methods are the following:

1. Aroma analysis

   Based on the methods of Baldwin et al. (1998) and Krumbein & Auerswald (1998), volatile compounds will be collected from the head space of sliced tomatoes and analysed with gas chromatography (GC) using sniff and MS-detection to verify the components most important for tomato flavour. Once the response factors in our setup are determined, head space volatiles of fruit from different treatments will be analysed on GC, enabling both the measurements of the specific compounds contributing to tomato flavour, and fingerprints for detection of general changes in composition of volatiles.

2. Sensory evaluation

   A panel composed of at least 7 trained assessors will evaluate the fruit for the following attributes: Fruit colour, sweetness, sourness, flavour intensity, firmness, skin colour, pulp colour, mealiness, aroma (scent), total preference.

3. Analyses of soluble solids, vitamin C content and organic acids.

   As described in Petersen et al. (1998)

4. Measurement of texture properties

   Will be determined by compression and penetration tests using penetrometers and Instron/texture analyser.

5. Analysis of trace elements.

   If this is carried out , the content of selected major and trace elements will be analysed by inductively coupled argon plasma optical emission spectrometry (ICP-OES) or high resolution inductively coupled argon plasma mass spectrometry (HR-ICPMS). The fruit can be analysed for Ca, P, S, Na, K, Mg, Cu, Fe, Mn, Si, and Zn by ICP-OES and for Se, Ni, Co, V, Mo, Pb, Cd and if possible B, Al, and Sn by HR-ICPMS.

6. Analysis of the storability of the products.

Year 2001

The aroma analyses are established using tomatoes from WP1, so they will be ready for use in 2002. Depending on the results of WP1 and other projects some of the material from first year of WP3 may be analysed using methods 2-4.

Year 2002 and 2003

Fruit from the experiments of WP3 will be evaluated using parallel analyses with methods 1-4, if relevant also method 5. Results will be analysed using multivariate analysis to show which cropping systems have significant influence on quality, which ones are best in overall values and to what extent the effects are systematic in relation to the data on nutrient availability in the substrate, including effects of nutrient imbalance.

The results of the instrumental measurements will be used to determine how the quality of fruit from the experimental cropping systems compares with the average and top values found by other investigators.

Deliverables

1) At least 2 popular papers in growers or food trade journals (Økologisk Jordbrug, Alimenta or similar) on the results of specific experiments and on final conclusions of the experiments
2) Scientific paper on the significance of cropping system for the aroma composition of tomato
3) At least one scientific paper on the significance of compost mixture and supplemental fertilisation for quality of tomato

4) Presentation at scientific meetings
5) Presentation at growers and advisors meetings

Milestones

1) Aroma analyses for tomato are established and validated, ultimo 2001.
2) Determining whether differences in cropping systems cause significantly different aroma compositions in tomato, summer 2002.
3) Determining whether the cropping system being tested produce tomatoes of a quality which is similar or superior to the standards generally found with the cultivar(s) in question, ultimo 2002.
4) Deciding whether and if so, how, the quality differences found among the tested cropping systems are so significant, that they partly determine which treatments will be tested at the commercial greenhouse installation, ultimo 2002.
5) Contribution to recommendation for cultivation programme for tomatoes and cucumber, 2003.

7. Implementation and time schedule

Table 3: Deliverables list

Deliverable No	Deliverable title	Delive-ry date	Meeting	Nature
WP1	**The nutrient dynamics and nutrient use efficiency of the current production systems**			
1	Two popular paper in growers journals	2001		Pup
2	Presentation at growers and advisors meetings		Meeting	Oral
WP2	**Development of plant based compost**			
3	At least 2 popular papers in growers journals development of composts based on crop materials, and their quality as nutrient source for cucumber.	2002/ 2003		Pup
4	Paper on the effect of the effect of different compost compositions on growth, yield and nutrient uptake by cucumber	2003		Pu
5	Paper on the significance of compost mixture and supplemental fertilisation for growth and temporal nutrient uptake of cucumber	2003	Int. symposia	Oral + Pro-in
6	Presentations at growers and advisors meetings		Meeting	Oral
WP3	**Project co-ordination, development and comparison of production systems for tomatoes**			
7	Project homepage	2001		Web
8	Two popular papers on the testing and comparison of cropping systems	2003/ 2004		Pup
9	Paper on the comparison of tomato growth in soil, limited beds, and the intermediate system.	2003		Pu
10	Paper on root growth and soil nutrient depletion of tomatoes.	2004		Pu

11	Presentation at scientific meetings	2003/ 2004		Oral
12	Presentation at growers and advisors meetings			Oral
WP4	**Quality evaluation of the greenhouse vegetables from contrasting cropping systems**			
13	At least 2 popular papers in growers or food trade journals	2002/ 2003		Pup
14	Paper on the significance of cropping system for the aroma composition of tomato	2003		Pu
15	Paper on the significance of compost mixture and supplemental fertilisation for quality of tomato	2003		Oral + Pro-in
16	Presentation at meetings for growers, advisors and others			Oral

Pu= International publications in books and journals
Re= Reports
Pro-in= Proceedings/abstracts at international symposia, conferences etc.
Pro-na= Proceedings/abstracts at national conferences etc.
Pup= Pupular papers
Oral= Oral presentations, lectures etc.
Web=Internet publication, decision support systems

8. Implementation and time schedule

Table 4: Time table

		2000									2001												2002												2003												2004						
	Month	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7
	WP1: On-farm description and analysis of production and management strategies for steers																																																				
1	Steer production on private farms+ welfare+economic models of steers ……	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x																						
2	Investigation of different winter feeding strategies								x	x	x	x	x	x							x	x	x	x	x	x																											
3	Study of supplements to and adaptation of calves to grazing		x	x	x	x	x	x							x	x	x	x	x	x																																	
M1	Comparison of grazing strategies for steers and calves								x												x																																
M2	Comparison of winter feeding strategies in steer production.														x												x																										
M3	Evaluation of models of welfare and production strategies.																											x																									
	WP2: Production strategies for steers on clover grass pastures																																																				
4	Study of herbage intake in steers and heifers			x	x											x	x																																				
5	Body condition scores	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x																											
M4	Estimation of feed intake by steers on clover grass pasture						x																																														
M5	Model for the use of body condition scores as a management tool in steer …..																											x																									
	WP3: Grazing systems for steers on marginal land																																																				
6	Study of performance of 1-year steers and heifers		x	x	x	x	x	x							x	x	x	x	x	x																																	
7	Measurement of herbage intake by steers and heifers															x	x																																				
8	Investigation of the effect of grazing strategies and a bioactive forage ……..														x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x																	
9	Analysis of fatty acids in steers in relation to fattening strategy and bioactive …																																x	x	x	x																	
M6	Comparisons of herbage intake in steers and steers and heifers																	x																																			
M7	Comparison of performance of 1-year grazing steers and heifers																					x																															
M8	Evaluation of the effect of different grazing strategies on production and …..																																				x																
M9	Establishment of the relationship between finishing strategy and fatty acids ….																																						x														
	WP4: Influence of different grazing strategies on biodiversity, forage quality																																																				
	and content of bioactive plants on marginal land																																																				
10	Study of sward production and quality														x	x	x	x	x	x							x	x	x	x	x	x																					
11	Description of the effect of grazing heterogenity on sward structure														x	x	x	x	x	x								x	x	x																							
12	Study of the dynamics in biodiversity								x	x						x	x	x	x	x	x	x						x	x																								
13	Inventory of plant species																x	x	x	x	x	x																															
14	Analysis of bioactive plant composition in relation to management strategy																x	x										x																									
M10	Evaluation of sward structure dynamics																				x																																
M11	Evaluate the content of bioactive plants in the swards with different botanical ..																					x																															
M12	Evaluation of bioactive plants, forage production and quality in relation to …																					x	x											x																			
M13	The dynamics in biodiversity are analysed																								x									x																			
	WP5: Preparation of extracts for estimation of direct anthelmintic effect of plant species																																																				
15	Production of plant extracts using a gut-mimetic system					x	x	x	x	x	x	x								x	x	x	x																														
16	Estimation of loss of metabolites in a gut-mimetic system										x	x	x																																								
17	Analyses of inulin and tannin concentrations in plants							x			x					x					x				x					x				x							x					x							
M14	Development of a gut-mimetic system for extraction of bioactive secondary ….									x																																											
M15	Extracts of cultivated and wild plant species for testing of anthelmintic activity								x	x	x												x																														

I.1 Organic production of cucumber and tomato grown in composted plant material from field crops

	WP6: Influence of bioactive forages on animal health with emphasis on parasitic infections																																																				
18	*In vitro* testing of plant extracts for activity against free-living parasite larvae	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x																																
19	*In vivo* testing of bioactive plants in parasite infected lambs		x	x	x	x	x	x							x	x	x	x	x	x							x	x	x	x	x	x																						
20	*In vivo* testing of bioactive plants in parasite infected pigs														x	x	x	x	x	x							x	x	x	x	x	x																						
21	Study of antiparasitic effects of chicory in pigs																				x	x	x	x									x	x	x	x																		
M16	Development of *in vitro* methods for evaluating anthelminthic activity									x																																												
M17	Comparison of *in vitro* anthelmintic activities of different plant extracts																					x																																
M18	Evaluation of anthelmintic effects of chicory in pigs																									x																				x								
M19	Assessment of the anthelmintic screening of different forages/plants in lambs																																	x																				
M20	Assessment of the anthelmintic screening of different forages/plants in pigs																																													x								
	WP7: Cultivation of bioactive forages																																																				
22	Study of limiting factors in establishment of selected crops		x	x	x	x	x	x	x	x																																												
23	Cultivation of selected crops in small field plots		x	x	x	x	x	x							x	x	x	x	x	x																																		
24	Cultivation of selected crops in larger fields for grazing lambs														x	x	x	x	x	x							x	x	x	x	x	x																						
25	Production of chicory silage														x	x	x	x	x								x	x	x	x	x								x	x	x	x	x											
M21	Laboratory establishment of bioactive crops completed									x																																												
M22	Analysis of data collected from large scale production of silage to pigs and steers																			x												x												x										
M23	Evalutation of bioactive stands from small plots or grazing studies																															x																						
	WP8: Influence of bioactive forages on meat and eating quality																																																				
26	Investigation of meat and eating quality in pigs fed chicory																				x	x	x	x									x	x	x	x																		
27	Study of the effect of finishing strategy and bioactive forage on meat and sensory quality in steers																																x	x	x	x																		
M24	Assessment of the influence of chicory on meat and sensory quality in pigs																									x																								x				
M25	Evaluation of finishing strategy and bioactive forage in relation to meat and sensory quality in steers																																						x															

I.1 Organic production of cucumber and tomato grown in composted plant material from field crops

8. Collaborative partners

FØJO-project VEGCATCH, there will be co-operation with the work packages of this project dealing with root growth of vegetable crops and with the value of green manure crops for nutrition of vegetable crops (N, P, K and S effects will be studied).

9. Budget

	2000	2001	2002	2003	2004
Danish Institute of Agricultural Science					
Salary (scientific)	211	343	530	577	187
Salary (technical)	56	147	475	445	0
Operation	64	213	364	285	20
Overhead	66	141	274	261	41
Total	397	844	1643	1568	248

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Thorup-Kristensen, K and Sørensen, J.N. 1999 Soil nitrogen depletion by vegetable crops with variable root growth, Acta Agric. Scand. Sect. B. Soil Plant Sci., 49: 92-97

Thorup-Kristensen, K and Van den Boogaard, R. 1999 Vertical and horizontal development of the root system of carrots following green manure. Plant and Soil 212: 145-153

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10. Appendix 1, Curriculum Vitae for the responsible scientists for each Work package:

Name **Kai Lønne Nielsen**

Born 13 June 1964

Education
1997: Ph.D. in Horticulture, Department of Horticulture, The Pennsylvania State University,Pennsylvania, USA.
1992: M.Sc. in Horticulture. Department of Agricultural Sciences. The Royal Veterinary and Agricultural University. Copenhagen, Denmark.

Employment
2000- Department of Fruit, Vegetable and Food Science, Danish Institute of Agricultural Science (DIAS)
1998-2000 Senior scientist. Department of Ornamentals. DIAS.
1997-1998 Scientist. Department of Ornamentals. DIAS.
1993-1996 Teaching Assistant in Plant Nutrition and Plant Physiology at The Dept. of Horticulture, The Pennsylvania State University, Pennsylvania, USA.

Other activities
1996-1997 Primary investigator. Field studies in Costa Rica. Partially

Oct. - Feb. Funded by The Danish Council for Development Research. The Ministry of Foreign Affairs, Denmark.

Co-supervisor for MSc and PhD students, from KVL, KU, CATIE (Costa Rica) and BSc students from the Netherlands.

Main research projects
1993-1997: Root architecture and phosphorus acquisition efficiency in common bean (*Phaseolus vulgaris* L.). Physiological studies, computer simulation and visualization
1996 to 1997: Fractal analysis of bean root architecture. A potential tool for studying phosphorus acquisition efficiency. Coordinating scientist.
1997 to 2000: OPKOT. Research programme concerning keeping quality, stress tolerance and vitality in ornamentals. Post doctoral fellow, root physiology and plant nutrition.
1999 to 2001: Testing phosphorus charged Compalox. Development of nutrient buffers. 1999 to 2002: The effect of reduced phosphorus supply on root development, carbon budget and quality. Danida project in collaboration with CATIE Costa Rica.

Research interests
Development of nutrient buffers. Development of methods for quality control of plant growth media. Analysis of and computer simulation of root architecture. Analysis of the effects of water and nutrient stress on root architecture and carbon allocation in plants (growth, respiration and assimilation)

Some recent publications
K.L. Nielsen, J.P. Lynch, H.N. Weiss (1997) Fractal geometry of bean root systems: correlations between spatial and fractal dimension. Am. J. Bot. 84, 26-33.
T.J. Bouma, K.L. Nielsen, D.M. Eissenstat, J.P. Lynch (1997) Estimating respiration of roots in soil: interactions with soil CO_2, soil temperature and soil water content. Plant and Soil 195, 221-232.
T.J. Bouma, K.L. Nielsen, D.M. Eissenstat, J.P. Lynch (1997) Soil CO_2 concentration does not affect growth or root respiration in bean or citrus. Plant, Cell, and Environment 20, 1495-1505.
K.L. Nielsen, T.J. Bouma, J.P. Lynch, D.M. Eissenstat. (1998) Effetcs of phosphorus availability and arbuscular mycorrhizas on the carbon budget of common bean (Phaseolus vulgaris L.) New Phytologist 139, 647-656.
K.L. Nielsen, C. Miller, D. Beck, and J.P. Lynch. (1999). Fractal geometry of root systems: Field observations of contrasting genotypes of common bean (Phaseolus vulgaris L.) grown under different phosphorus regimes. Plant and Soil 206, 181-190.
T.J. Bouma, K.L. Nielsen, B. Koutstaal (2000) Sample preparation and scanning protocol for computerized analysis of root length and diameter. Plant and Soil 218, 185-196.

Name	**Kristian Thorup-Kristensen**
Born	25 September 1961
Education	1987 M.Sc. in agriculture from The Royal Vet. and Agricultural Univ. (KVL) 1995 Ph.D. degree in Plant Nutrition and Soil Fertility
Employment	1987 to 1988, Scientist at The Royal Vet. And Agricultural Univ. 1989 to 1997 Scientist at the Danish Inst. Agric. Sci. Since 1997 Senior Scientist at the Danish Inst. Agric. Sci. Since 1998 Head of Research group for Vegetable production, Danish Inst. Agric. Sci.
Other activities	Censor at KVL, Institute of Agricultural Science Co-supervisor for two PhD students, one at KVL and one at The Sweedish Agricultural University, Uppsala.
Main research projects	1989 to 1992: Catch crops in vegetable production under the "Green fields initiative" 1993 to 1997: Development of crop models as the basis for decision support systems for Integrated Production (IP), as active scientist and project leader. 1993 to 1997: Project on the use of green manures for organic vegetable production. 1993 to 1997: Project on root development of green pea genotypes, as part of a project for development of green pea production methods. 1996 to 1999: Project on catch crops and N husbandry in organic vegetable production, under the first DARCOF initiative, as active scientist and project leader 1996 to 1999: Project on crop rotation for organic vegetable production under the first DARCOF initiative.
Research interests	The main topics have been N utilization, root growth of vegetables and catch crops and effect of catch crops and green manure and organic crop rotations. The work has focused on growth, and the significance of differences in root growth for N utilization. The research has also been directed at applied aspects of this, how to improve the utilization of catch crops and green maures to design crop rotations with higher NUE and lover losses. The results have been communicated through 13 papers in scientific journals, more than 20 papers in proceedings from workshops etc., and 25 papers in farmers journals etc.
Some recent publications	Thorup-Kristensen, K. 1994. An easy pot incubation method for measuring nitrogen mineralization from easily decomposable organic material under well defined conditions, Fertilizer Research, 38, 239-247 Thorup-Kristensen, K and Van den Boogaard, R. 1998 Temporal and spatial root development of cauliflower (Brassica oleracea L. var. botrytis L.), Plant and Soil 201: 37-47 Thorup-Kristensen, K and Nielsen, N.E. 1998 Modelling and measuring the effect of nitrogen catch crops on nitrogen supply for succeeding crops. Plant and Soil 203: 79-89. Thorup-Kristensen, K. 1998. Root development of green pea (*Pisum sativum* L.) genotypes, Crop Science 38: 1445-1451. Thorup-Kristensen, K and Van den Boogaard, R. 1999 Vertical and horizontal development of the root system of carrots following green manure. Plant and Soil 212: 145-153 Thorup-Kristensen, K. (1999) An organic vegetable crop rotation aimed at self-sufficiency in nitrogen. In: Olesen, J.E., Eltun, R., Gooding, M.J., Jensen, E.S. & Köpke, U. (Eds) Designing and testing crop rotations for organic farming. DARCOF Report no. 1. p 133-140

Name **Morten Nielsen**

Born 9 December 1959

Education

1988 M.Sc. Horticulture from The Royal Vet. And Agricultural Univ. (KVL)
1996 Ph.D. Food Science

Employment

1986 -1987	Scientific assistant at the Danish Royal Veterinary and Agricultural University, Department of Plant Pathology.
1987-1987	Received a scholarship at the Danish Royal Veterinary and Agricultural University.
1988-1989	Scientific assistant the Danish Potato Improvement Station in Vandel.
1989 to	Scientist at the Danish Institute of Agricultural Sciences, Department of Horticulture.

Other activities

Assistant coordinator of EU-proposal on the use of ultrasonics for quality evaluation of vegetables, which was on the reserve list for funding in first call of the 5th Framework Programme.

Main research projects

1989-1992: Controlled atmosphere storage of fruits and vegetables
1992-1995: Texture Measurement of Fruits and Vegetables by the use of Ultrasonics.
1996-1998: Quality of organically grown carrot roots
1998-2002: Future apple production – use of disease-resistant apple cultivars and pre-treatments before storage
1998-2003: Influence of plantation system, rootstock and nitrogen supply on productivity, ripening capacity and product quality of apples.
2000 Optimising the sensory and nutritional quality of tomatoes (responsible for quality evaluation).

Research interests

Main focus is on texture and mechanical properties of fruits and vegetables in relation to biochemical and physiological changes during storage and processing. Main topics include: (1) quality change during blanching and cooking of potatoes and carrots; (2) influence of pre-treatments, like heat and CO_2, on storage performance in apples; (3) optimising texture and other quality characteristics during storage and shelf-life in relation to harvest date, and temperature, humidity and atmosphere composition during storage of apples and pears. Analysing methods are mainly based on mechanical texture measurements by rheometer, uniaxial compression, ultrasonic measurements and image analysis of microstructure studies.

Some recent publications

Nielsen M. 1993.
Influence of harvest date and controlled atmosphere on storage behaviour of pear (Pyrus communis cv. Clara Frijs). Acta Agric. Scand., Sect B. Soil and Plant Sci. 43, 185-191.

Nielsen M. , 1996.
Texture Measurement of Fruits and Vegetables by the use of Ultrasonics. Ph.D. Thesis, Department of Dairy and Food Science, The Royal Veterinary and Agricultural University.

Nielsen M. & Martens H.J., 1997.
Low frequency ultrasonics for texture measurements in cooked carrots (*Daucus carota L.*). Journal of Food Science 62, 1167-1170, 1175.

Nielsen M., Martens H. J. & Kaack K., 1998.
Low frequency ultrasonics for texture measurements in carrots (*Daucus carota L.*) in relation to water loss and storage. Postharvest Biology and Technology 14, 297-308.

Thybo, A. K., Nielsen, M & Martens M., 2000.
Influence of uniaxial, compression rate on rheological parameters and sensory texture prediction of cooked potatoes. J. of Texture Studies 31, 25-40.