Project description

Organic protein feed and edible oil from oilseed crops

PART 1: The KMB project

1 Objectives

The principal objective of the project is to obtain knowledge for secure production of high-quality proteins for livestock feeds and edible oil for human consumption in Norwegian organic farming based on oilseed crops.

Sub-goals:

1. Map the potential for use of winter rape (*Brassica napus* L. var. *oleifera* Metzg.) and winter turnip rape (*Brassica rapa* L. var. *oleifera* Sinsk.) in Norway
2. Minimisation of problems with volunteers of spring turnip rape
3. Develop cultivation practices on nutrient supply for organic oil-seed crops
4. Establish knowledge on the feed quality of organically grown protein crops
5. Establish knowledge on the content and fatty acid composition of organically grown oil seed crops

2 Frontiers of knowledge and technology

It has been announced that husbandry in organic farming from 2005.08.24 onwards should be based entirely on an organically produced diet (Council for The European Union, 1999). However, in July 2005 it became obvious that this was not achievable within the EU/EØS countries because of shortage on the European market of protein feeds for production of concentrates. As a temporary arrangement, therefore, it is allowed to use up to 5% conventionally produced feedstuffs for ruminants until 2007.12.31. For poultry and pigs one has agreed on a gradual decrease in the use of conventionally produced feed from 15% in 2006-2007 to 10% in 2008-2009 and 5% in 2010-2011 (Debio, 2006).

Fishmeal is currently a vital constituent in concentrates and secures the need for high-quality proteins. However, as a precaution to avoid any chance of contamination with prions in meat bone meal, which in many EU-countries is commonly treated within the same production and transport channels, the EU-countries have forbidden the use of fishmeal in production of concentrates for the organic ruminant husbandry (Council for The European Union, 2003). A similar ban is expected in Norway. Until further notice fishmeal will be allowed used in concentrates for poultry and pigs. Cost-effective production of concentrates will most likely be performed on a limited number of plants and probably without the use of fishmeal. Since concentrates for ruminants, poultry and pigs in Norway commonly is treated within the same productions and transports channels, a ban against the use of fishmeal in organic concentrates for ruminants will, therefore, also eliminate the use of fishmeal for poultry and pigs. Fishmeal might be used in on-farm production of concentrates for poultry and pigs, but this is rarely done in Norway because of high production costs on the relatively small farms. Such a practise is also difficult to control by governmental authorities (Glende, 2005. Pers. com.).

An other obstacle in the production of concentrates for use in organic farming is that extracted soy-beans meal which is the main protein source in conventional concentrates, is not allowed used in organic husbandry. This is caused by a general ban on the use of chemical extraction in fodder production (Debio, 2006).

In conclusion there is an increased need for organically produced feedstuffs for production of concentrates in the Norwegian organic husbandry.

Currently, pea (*Pisum sativum* L.) is the most common cultivated protein-rich crop in organic agriculture in Norway. However, as a sole addition to a grass-based fodder ration, peas are not sufficient to meet the nutritional demand. Because the growing technique of pea is well known, the main focus will be on protein from oilseed crops which have a protein quality that complements the protein quality in peas.

During the last decade there has been an increased consume of edible oils compared to margarine and butter. In 2005 the fastest growing marked was on rapeseed oil (ACNielsen, 2006). It is due to introduction of a Norwegian product (Odelia) and the health benefits of the oil. There is not known if organic rapeseed oil gives a different fatty acid composition than ordinary rapeseed oil. Tests performed on organic rapeseed oil from the southern part of Norway (Østfold county) showed no difference in fatty acid composition compared to conventionally grown seeds. As this was only performed for one specific cultivar at only one location more research and field trials are needed.

2.1 Challenges in cropping of oilseed crops under Norwegian growing conditions

In a literature study prior to this application (Olberg *et al.*, 2005), we have determined and prioritized the main factors that limit the use of oil-seed crops in organic farming in Norway as follows:

	Critical factor	Cultivation relevance
Spring turnip rape	Persistent shed seeds Nutrient supply/crop rotation Insects (pollen beetles (*Meligethes)* turnip flea beetles (*Phyllotreta*) Diseases	Of interest in most grain-producing regions if problems connected with dormant seeds are solved
Spring rape	As for spring turnip rape, but problems with persistent shed seeds are even higher because of late harvesting	Currently not relevant in organic agriculture
Winter turnip rape & winter rape	Winter survival Nutrient supply Persistent shed seeds Insects	Of interest in wheat-producing regions
Winter and spring Camelina (*Camelina sativa* L. Crtz., *Brassicaceae*)	Winter hardiness Growth period Yield stability	Of interest for organic cultivation

Solutions to overcome the most important challenges connected with these factors will be focused upon in the present project.

Within an organic farming context, there are several advantages in cropping winter oilseed crops as compared with spring oilseed crops. Early start of the growth in spring reduces problems connected with insects and results in higher yields. Moreover, early harvesting gives more time for control of shed seeds. The problem with shed seeds in organic cultivation of winter rape is presently dealt with under reasonably similar conditions as ours (Wallenhammar, Pers. com.) and will not be focused on in this project. Poor winter survival is however, the main obstacle for cropping of winter rape and winter turnip rape under Norwegian growing conditions. However, new winter hardy cultivars, together with new and improved cultivation techniques, can probably make it interesting to grow these crops in some areas of Norway. A newly started project "Opportunities for Norwegian production of biodiesel from agricultural crops" (www. Bioforsk.no) seeks solutions to these tasks, and cropping methods for improved winter survival will not be focused on in this project. Here we will focus on mapping of the climatic limitations for winter rape and winter turnip rape in Norway and the nutrient supply.

As spring turnip rape can be grown in most of the cereal growing area of Norway (Åssveen & Heir, 2001) it is the oil crop with the larges cropping potential. If the problem with persistent shed seeds can be solved, it can also be actual for organic cropping. On the other hand, spring rape is very late ripen and the problems with shed seed may be even larger than for spring turnip rape, thus it do not seem actual for organic cropping in Norway.

Camelina or gold-of pleasure (*Camelina sativa* L. Crantz) is another oil-seed crop, which may have considerable interest for organic cropping in northern areas (Alen *et al.*, 1999). It has a low nutrient requirement, no seed dormancy, less problems with insect damage than rape and turnip rape and the seed quality makes it actual both for edible oil and animal feed (Putnam *et al.*, 1993; Vollmann *et al.*, 1996).

Insects like pollen beetles and turnip flea beetles are not an annual problem in conventional cropping of turnip rape in Norway, but they may be a serious problem in organic cropping of rape and turnip rape. Except for registration of possible insect damage, the insect pests will not be prioritised in this project.

2.2 Mapping climatic limitations for winter oilseed crops in Norway

Agroclimatic mapping of crop growth conditions has traditionally been based on long-term means of climatic factors, mainly temperature (Skjelvåg *et al.*, 1992). Geographical information systems (GIS) have opened for approaches that may quantify the risks or the crop security by taking the annual and seasonal variation in weather at freely chosen locations into account (Tveito *et al*., 2005, Skjelvåg *et al*., 2006). Risk analyses may be of special interest in organic agriculture with its requirements to homegrown feed (Lien *et al*., 2005).

A little more than a decade ago crop growth models were not widely used in agroclimatic mapping (Skjelvåg *et al*.,1992). This is still much the situation, but in connection with studies of climate change impacts there are other examples (Olesen & Bindi, 2002).

Overwintering impacts on crop growth and development have mostly been studied as effects of various stress factors. Relationships to climatic factors have been documented, but a quantification aiming at an agroclimatic mapping are mostly lacking (Skjelvåg *et al*., 1992). One reason may be that this will be more of a risk analysis than a quantification of long term average conditions. Risk analysis requires quite another access to tools for handling of weather data than so far mostly available. An overwintering model of winter wheat under Norwegian conditions is being developed in a doctoral programme (Bergjord & Skjelvåg, 2005).

GIS tools for interpolation of daily weather records have opened for taking both soil and weather data into use to characterise the natural resource base for crop production. Various crop growth models are the tools that can translate soil and weather records into agronomically meaningful characteristics such as crop security or risk of failure. An example of such a combined model tool has been described for spring barley by Aune *et al*. (2005).

2.3 Persistent shed seeds

When cropping oilseed rape the amount of seed losses is high before and during harvest (e.g. Gulden & Shirtliffe, 2003; Gruber *et al*., 2005). Winter rape is commonly used in more southern parts of Europe and the problem with shed seeds developing into a weed problem have been studied in several works. Rapeseeds exhibit little dormancy (primary dormancy) at the time of seed sheds (Gruber *et al*., 2004). However, under special environmental conditions the seeds become secondary dormant and thus develop into a persistent seedbank and turn into a long lasting weed problem the subsequent years (Pekrun *et al*., 1998). Pekrun *et al.* (1997a; 1998) found in laboratory studies that secondary dormancy was induced when seeds were exposed to water stress and darkness, and that dormancy was broken by alternating warm and cold temperatures. This was confirmed by field studies showing that the seeds become dormant if they were incorporated into dry soil and, thus, can be very persistent. To avoid secondary dormancy a delay of tillage in autumn for four weeks have shown to be effective (Pekrun *et al*., 1998, Gruber *et al*., 2005). The use of zero tillage are shown to give some contrasting results (e.g. Gruber *et al*., 2005). There are differences in seed dormancy between cultivars of winter oilseed rape (Pekrun *et al*., 1997b, Gruber *et al*., 2004).

In this project we are focusing on spring turnip rape. However, some of the results on rape may be used also for turnip rape. As for winter rape, different cultivars of spring rape vary in potential for development of secondary dormancy (Pekrun *et al*., 1997b; Gulden *et al*., 2004a). Therefore, it may be possible to choose cultivars with low dormancy potential in organic farming. Further Gulden *et al*. (2004b) found that increasing temperature and water stress enhanced development of secondary dormancy, as well as deep burial by tillage. Deep burial may also result in high persistence of spring turnip rape (Sparrow *et al*., 1990, ref. Gulden *et al*., 2003). In Canadian studies there were little differences between zero tillage and more intensive tillage in persistence of seeds of spring rape and spring turnip rape (Gulden *et al*. 2003). Gulden *et al*. (2003) stated that they did not succeed in using the spring rape assay conditions to induce dormancy in spring turnip rape, and could not classify the two cultivars studied.

Based on the above results, the basic idea is to ensure a high degree of germination of shed seeds in autumn and avoid development of secondary dormancy. Young plants will then be killed by frost trough winter or can be controlled mechanically before sowing new crops the following spring. In Canadian experiments spring rape emerged in spring and not in autumn (Gulden *et al*. 2003). However, Norwegian experience is that a lot of seeds of spring turnip rape germinate in autumn. Eventual cultivar differences needs to be investigated for the cultivars of spring turnip rape grown in Norway. The use of weed harrowing in cereals with normal spacing is a common weed control method in organic farming. This method does not have a very good effect on *Brassiceae* species (Koch, 1964) and will probably not be efficient against large numbers of volunteer spring turnip rape either. If most of the seeds germinate in spring, it might be necessary to provoke germination in spring through repeated establishment of seedbeds (false seedbed). Such a treatment delays the sowing of new crops but early crops, like early cultivars of spring barley, can be used. Another treatment that possibly can be used to control the weed problem following oilseed cropping is to establish new grain crops with wide spacing between rows and inter-row cultivation during early summer (I.A. Rasmussen, Pers. com.).

2.4 Nutrient supply in organic oilseed crops

Oilseed crops need ample supplies of nutrients (Rathke *et al.*, 2004) and this represents a challenge in organic cultivation. In particular if oilseeds are cropped on farms with no or few animals. In Denmark intercropping of oilseed rape, barley and peas has been investigated and the results indicate a benefit from nitrogen (N) fixed in association with rape and pea (Andersen *et al.*, 2004). However, for Norwegian conditions where we have to focus on both the problem with shed seeds in spring turnip rape, and different cropping methods to improve winter survival in winter oilseed crops, intercropping does not seem to be of current interest. The most actual approach for nutrient supply seems to be to utilise a combined effect from pre-crops and farmyard manure (Engström, 2006. Pers. com.)

Oilseed crops have a high content of sulphurous amino acids (Uhlen *et al.*, 2004) which is very important for the feed quality, as there are few other sources for sulphurous amino acids in the production of concentrates for livestock in organic agriculture. As sulphur (S) deposition from the atmosphere has decreased the last decade (Miljøstatus i Norge), S deficiency is an increasing problem (Hansen *et al.*, 2005; Nilsson, ongoing project). It is also known that a balance between N and S is necessary to obtain optimal yield and quality of oilseed crops (Fismes *et al.* 1999). Thus, the S as well as the N supply has to be taken into consideration in organic oilseed cropping.

2.5 Use of protein-rich crops for concentrate

The content of crude protein is often low in organic ley (Olberg *et al.*, 2005), resulting in insufficient protein content to meet the nutritional demands of e.g. high-producing milking cows. Feedstuffs with additional protein are, therefore, normally added to the ration. Currently, pea is the most common cultivated protein-rich crop in organic agriculture in Norway. For ruminants peas has a low bypass protein content compared to common protein supplements such as rape meal and soybean meal (Corbett, 1997). This, and the rather low protein content make it difficult to formulate rations for high producing animals utilising large amount of peas. Other high-protein crops with complementary properties are therefore needed to meet the demand in feed quality for ruminant, pigs and poultry. Oilseed crops, which are rich in both fat and protein, are of considerable interest if problems related to their cultivation are solved.

The content of important chemical constituents such as crude protein, crude fat, NDF (neutral detergent fibre), amino acid composition and rumen degradability of protein varies much between crops. High rumen degradability of protein is usually resulting in low AAT-value (amino acids absorbed in the small intestine) and high PBV-value (Protein balance in the rumen) (Madsen *et al.*, 1995). In addition, turnip rape and rape are rich in unsaturated fatty acids, which restricts the content of oilseeds that can be used in the daily feed ration for ruminants. However, the content of oilseed in the ration can be increased if fat is removed through squeezing or compression. Expeller cakes produced in this way usually have an increased protein value for ruminants because the heat produced in the treatment reduces the rumen degradation of protein, resulting in an increased AAT-value and reduced PBV-value of the feed. The oilseeds are rich in S-containing amino acids and, nutritionally, complement the amino acids found in pea. The mentioned crops do also contain elements which different animal species have various tolerances for (Wollenweber *et al.*, 2002).

We currently have very limited experience with oilseed crops in organic agriculture and we do not know to what extent limitations in the N supplement will influence the content of crude protein. Experiments with conventionally grown oilseeds crops show great difference in fat and protein content according to the N fertilization rate (Rathke *et al.*,2004; Asare &Scarisbrick, 1995). N and S application have increased the seed glucosinolate concentration (Asare & Scarisbrick, 1995). Organic manure and mineral fertilizer may perhaps result in differences in the feed quality. Experiment with long-term cattle manure application to rape increased the total N content and decreased the oil content in seed (Hao *et al.*, 2004). There is a considerable and urgent need for chemical analysis and knowledge about the rumen degradability of protein, starch and NDF and intestine digestibility of protein in organically grown protein-rich crops in order to plan the production of concentrates for the Norwegian organic husbandry in the future.

2.6 Quality of edible oils from organically grown oiled crops for human consumption

Rapeseed oil is today the only Norwegian produced edible oil on market. Rapeseed oil is well known for the high content of linolic acid (C18:2) and a substantial amount of the essential linolenic acid (C18:3) (Gunstone, 1994). Linolenic acid is known for its health benefits like reduction of risk for cardiovascular diseases. Crude cold pressed rapeseed oil has a relatively high content of phytosterols compared to other edible oils, and are unique for the content of isothiocyanates which are decomposing products from glucosinolates.

Rapeseed oil consists mainly (95%) of triacylglycerols (TAG). Non-triacylglycerols, also known as minor components or unsaponifiable matter, make up the remaining 5%. They are primarily composed of phospholipids, tocopherols, tocotrienols, flavonoids, other phenolic compounds, pigments (carotenoids, chlorophylls), sterols, free fatty acids, and mono- and diacylglycerols (Shahidi & Shukla, 1996). Several classes of these components might be present in various oils and contribute to its oxidative stability (Hamilton, 1994; Shahidi *et al*., 1997). Plant oils containing high levels of polyunsaturated fatty acids are susceptible to oxidation, resulting in an alteration of major quality-control parameters such as colour, flavour, aroma, and nutritive value, affecting suitability for consumption (Huang *et al*., 1995, Lampi & Kamal-Eldin, 1998; Lampi *et al*., 1999; Lampi & Piironen, 1998). In addition, several compounds with antioxidant properties are either removed or changed during the processing and refining process.

During the last years there has been an increased focus on phytostereols and their effect to lower blood cholesterol levels (Patel, 2006). Long-term use of phytosterol-ester enriched vegetable oil spreads has been evaluated to be safe (Lea, 2006). Margarine with such sterols has been introduced on the Norwegian market lately. Rapeseed oils contain phytostereols naturally, which can have the same decreasing effect on the cholesterol level. Another group of compounds present in the crops from the *Brassicaceae* family, is the glucosinolates. Certain hydrolysis products of glucosinolates have shown anticarcinogenic properties (van Poppel, 1999). But, some of these sulphuric compounds have anti-nutritional and toxic properties (Fenwick *et al.,* 1983). It has been shown that rapeseed phenolics were excellent antioxidants toward oxidation of lipids, and that rapeseed oil (crude) phenolics were effective radical scavengers (DPPH test) (Vuorela *et al.,* 2005). Little information is published on to what extent they are transferred to the oil during rapeseed processing, and it is important to include analysis of these compounds in the quality control of organic grown oil crops.

3. and 4. Research tasks (3) and methods (4)

The project will be organised with work packages (WP's) and tasks within each WP. In the following the tasks and methods for each of the four WP's are described.

WP 1. Mapping of potential area for use of winter rape and winter turnip rape in Norway

The objective of the mapping work is to quantify the overwintering and growth conditions of winter rape and winter turnip rape in their prospective areas of cultivation in Norway.

Task/Objective 1: Develop an overwintering model of rape and turnip rape based on standard weather and soil type records.
Task/Objective 2: Develop models of phenological rate of development during the whole life cycle of the winter rape and winter turnip rape.
Task/Objective 3: Produce maps of overwintering and growth conditions of winter rape and winter turnip rape on prospective cultivation areas with soil type mapping.

<u>Methods</u>

An overwintering model of winter wheat under Norwegian conditions will be used as an example model (Bergjord & Skjelvåg, 2005). This model was first developed in Canada (Fowler *et al*., 1999) but is now further developed with new functional relationships needed for our climatic conditions. The key characteristics of the model are the estimation of state of vernalization and of frost hardiness, the latter determined by artificial freezing tests of LT_{50}. The input variables are (soil) temperature at the stem apex and snow cover. Estimated frost hardiness and overwintering stress will be related to spring growth potential of the plants. One may assume that the modelling procedures of the rapeseed crops will be corresponding to those applied in winter wheat. We expect the same model concept to be applicable to either rapeseed species, which may show variation in coefficients and constants of the model.

Data for development of an overwintering model of rapeseed species must be provided from plants that are brought to overwintering under different climates. Four locations have been chosen for field experiments during one winter. The site with the most marginal overwintering conditions will be in Central Norway (The Norwegian Institute for Agricultural and Environmental Research (Bioforsk) Grassland and Landscape Division, Research Farm Kvithamar, 63° 30'N, 10° 52'E, 40 m altitude), the site representing areas with considerable areas expected will be in south east inland

(Bioforsk Arable Crop Division, Research Farm Apelsvoll, 60° 42'N, 10° 51'E, 250 m altitude), a third site will be in a more favourable climate (The Norwegian University of Life Science (UMB), Research Farm Vollebekk, 59° 40' N, 10° 50' E, 80 m altitude), and a forth site will be run in cooperation with the Swedish University of Agricultural Sciences (SLU), Lanna Research Station 58° 20' N, 13° 7' E, 75 m altitude). Plants will be raised in flats and placed such that the flats can be brought in at certain times during the winter. Sampling will take place at least once every month for freezing tests. Parallel to the freezing test plants must be brought in for growth tests in a standardized climate for a period of three weeks. This is to quantify their development in vigour and growth potential during winter towards spring. This procedure is the same that has been used successfully by A.K.Bergjord in her doctoral work on winter wheat.

During the whole life cycle from sowing to seed ripeness a model of phenological rate of development is needed. The data to develop such a model will be provided by a separate observation programme in the cultivar performance tests of the Biodiesel project which will be established at the three first places mentioned for the overwintering experiment.

The mapping has to start with provision of soil type data from The Norwegian Institute of Land Inventory (NIJOS). Soil type units will be characterised by geographical coordinates, altitude and soil moisture capacity. Further calculations will take place at The Norwegian Meteorological Institute (met.no), where daily weather records are interpolated to each individual soil type unit, with a minimum size of 0.4 ha. The method has been fully described by Aune *et al.* (2004).

The met.no needs a model to estimate soil temperature from standard weather records. A simple model that will be operational in this context has been developed by Helge Bonesmo, and it will be used in A.K. Bergjords doctoral work. This soil temperature model, as well as the overwintering model, have to be incorporated into the FORTRAN programmes of met.no. Series of daily weather data for periods of twenty years are required from all relevant weather stations to make reliable estimates of annual variation and risk calculations. Maps can be made available on electronic medium as well as on paper.

WP 2. Minimisation of problems with volunteers in spring turnip rape

To gain knowledge on selected factors that influence germination of spring turnip rapeseeds and develop methods for minimisation of volunteer spring turnip rape, various types of experiments should be performed.

Task 1. Investigate factors that induce secondary dormancy in spring turnip rape

In winter rape and spring rape dry conditions, higher temperature and burial of shed seeds/darkness shortly after harvest can induce secondary dormancy (Pekrun *et al.*, 1997a; Gulden *et al.*, 2004b). Information on what environmental conditions that induce secondary dormancy is crucial for how to manage volunteer spring turnip rape in organic cropping systems. Since studies have shown that there are differences in cultivars concerning the potential for development of secondary dormancy in oilseed rape, the actual cultivars of spring turnip rape for Norwegian conditions should be tested in this respect.

Hypothesis 1: Dry conditions, higher temperature and burial of seeds/darkness induce secondary dormancy in spring turnip rape, i.e. the same factors as in winter rape and spring rape.

Hypothesis 2: There are cultivar differences in potential for development of secondary dormancy in spring turnip rape.

<u>Methods</u>

Newly harvested seeds of spring turnip rape from separate field trials at the Research Farm Apelsvoll will be submitted to different treatments under controlled conditions (climate chambers) in the laboratory at Bioforsk, Plant Health and Plant Protection Division. We will determine how the degree and timing of soil burial/darkness and how water stress/moisture and temperature affects seed germination and dormancy of actual cultivars of spring turnip rape. We will determine if there are any differences in seeds shed before harvest, seeds that are harvested by a combine and seeds that are stored for short periods. The experiments will be repeated twice (two years).

Task 2.Develop crop management techniques to control volunteer spring turnip rape

Hypohesis: It is possible to manage volunteer spring turnip rape by choosing the right time for cultivation and cultivar(s) with low potential for secondary dormancy in combination with various mechanical weed control treatments in spring (false seedbed, inter-row harrowing or weed harrowing) and eventually early cropping species/cultivars.

<u>Methods</u>

Field trials will be performed in 2006-2009. Experimental sites, homogeneously sown on top of the soil surface in autumn with newly harvested spring turnip rape seeds, will be established at Research Farm Apelsvoll and Bioforsk, Plant Health and Plant Protection Division, Ås. Two types of experiments will be performed:

A. In a first phase, we will determine to what extent primary soil tillage intensity and -timing in autumn/early spring will influence the amount of seeds and emerged spring turnip rape in the following cereal crop. The experiments will be laid out in as randomized block designs with three replicates in 1996/1997 and 1997/1998. Tentative tillage treatments are:

1. harrowing immediately after sowing shed seeds + late autumn ploughing
2. harrowing 2 weeks after sowing shed seeds + late autumn ploughing
3. harrowing 4 weeks after sowing shed seeds + late autumn ploughing
4. harrowing 0, 2 and 4 weeks after sowing shed seeds + late autumn ploughing
5. no tillage in autumn + ploughing in spring

The number of emerged plants of spring turnip rape at each time of tillage treatments, one month after sowing the cereal crop and at harvest will be assessed. Soil moisture at each treatment in autumn will be determined. Soil samples will be taken in spring before sowing and the amount of turnip rapeseeds in the soil will be determined.

B. In another type of experiments various mechanical weed control methods in the following crop will be investigated. To ensure an even infestation, fields will be sown on soil surface with spring turnip rape in the previous autumn and receive the autumn treatment from the first year of exp. A that give the highest emergence the following year. The experiments will be laid out as randomized block designs with three replicates in 1997/1998 and 1998/1999. Possible treatments are weed harrowing, inter-row cultivation in cereals crop with wide spacing (20 cm), repeated seedbed cultivation (false seedbed) combined with delayed sowing of an early cultivar of spring barley and combinations of various treatments.

The number of emerged plants of spring turnip rape at each time of treatments, one month after the last treatment and at harvest will be assessed. Soil samples will be taken in spring prior to the first sowing in spring to determine the amount of turnip rape seeds in the soil.

As results are obtained from trials under controlled conditions (task 1), these will be incorporated into the experimental set up for validation of cultivation techniques and cultivar choices.

WP 3. Cultivation practices for nutrient supply of oilseed crops

Task 1. Ensure sufficient nutrient supply in spring oilseed crops

As rape and turnip rape are nutrient demanding species the nutrient supply is a special challenge for these crops. In the most actual areas for growing of these crops in Norway there are in general little livestock farming and limited amounts of farmyard manure. Thus, in addition to knowledge on nutrients effect of farmyard manure we need knowledge on how to utilise pre-crop effects as nutrient source for rape and turnip rape in organic farming. Sufficient S supply is also a special challenge in organic growing of rape and turnip rape which will be focused on.

Camelina has not been grown commercially in Norway, however based on experience from conventional farming in e.g. Finland it appears to be an actual crop also for organic farming. Here we will focus on the agronomic characteristics in organic cropping of Camelina.

Hypothesis 1: Green manure crops in the crop rotation can replace farmyard manure as nutrient source in growing of spring turnip rape.

Hypothesis 2: Additional fertilization with S is necessary for optimal yield and amino acid composition of spring turnip rape.

Hypothesis 3: Spring seeded Camelina is an alternative crop to rape and turnip rape with regard to yield and yield stability.

Methods

Fields with peas, spring sown green manure and barley will be established as pre-crops in the spring of 2006, 2007 and 2008 on the organic research area at Research Farm Apelsvoll and at Lanna Research Station, in the spring 2007 and 2008. Split-plot experiments with four nitrogen levels (0, 40, 60 and 80 kg ha^{-1} in organic fertilizer) on main plots and turnip rape and camelina with and without S ($MgSO_4$) on sub-plots will be placed in each pre-crop field with three replications in 2007, 2008 and 2009 at Apelsvoll and at Lanna in 2008 and 2009. For protection against bird damage in the autumn, the experiments will be covered by nets and turnip rape will be grown around the experimental plots. The row spacing will be 10 cm.

At each experimental site, weather data like air and soil temperature and precipitation will be recorded. The mineral N content for each treatment will be determined at establishment of the trials in the in the spring and after harvest. The dry matter yields, oil and protein content and seed size will be recorded as well as time of maturing, disease and insect damage.

Task 2. Ensure sufficient nutrient supply in winter rape and winter turnip rape

Winter rape and winter turnip rape needs even more nutrients than the spring types. In addition to sufficient nutrients in the yielding year it is very important with good establishment and optimal plant size in the in the autumn. In areas with good growing conditions in the autumn the N availability do not seem to be so important for the yield (Colnenne *et al.*, 2001), however in areas with cool and short autumn, factors affecting early growth like nutrient availability, may be important.

Hypothesis 1: Utilisation of green manure crops in the crop rotation is not sufficient for optimal autumn growth of winter rape and winter turnip rape.

Hypothesis 2: Green manure crops in the crop rotation can replace spring application of farmyard manure as nutrient source in growing of winter rape and winter turnip rape.

Methods

Fields with spring sown green manure and barley will be established as pre-crops in the spring of 2006, 2007 and 2008 on the organic research area at Apelsvoll and at Lanna in the spring 2007 and 2008. Split-split plot experiments in winter rape and in winter turnip rape with autumn fertilization (0 and 40 N kg ha^{-1}) on main plots and spring fertilization (0, 40, 60 and 80 kg N ha^{-1} with and without S) on sub plots will be placed in each pre-crop field in 2006, 2007 and 2008 at Apelsvoll and in 2007 and 2008 at Lanna. Each experiment will have three replications.

The row spacing will be 20 cm, allowing inter-row weeding. For protection against bird damage in the autumn the experiments will be covered by nets and rape will be grown around the experiments.

At each experimental site weather data like air and soil temperature, precipitation and time of snow cover will be recorded. The mineral N content for each treatment will be determined in late autumn in the establishing year and after harvest. Plant height, root length and thickness will be measured in late autumn and number of plants will be counted both in the autumn and spring. Dry matter yields, oil and protein content and seed size will be recorded as well as time of maturing, disease and insect damage.

WP 4. Quality for feed and food

Task 1. Quality of organically grown protein crops for livestock concentrates

We currently have very limited experience with oilseed crops in organic agriculture and we do not know to what extent limitations in the N supplement will influence the content of crude protein. Organic manure and mineral fertilizer may perhaps result in differences in the feed quality. It is expected that different S supply will alter the amino acid composition of both oilseed crops and grain legumes.

Hypothesis 1: There is a pronounced variation in the quality of protein-rich crops dependent on whether they are grown conventionally or organically

Hypothesis 2: There is a pronounced variation in the quality of protein-rich crops dependent on climatic and nutritional conditions.

Methods

Samples of rape, turnip rape and pea from the experiments in WP 3 will be sampled and analysed chemically for ash, starch, protein, NDF (neutral detergent fibre), total fat, sugar, the aminoacid methionine, lysine, cyctein, tryptophan, threonine and arginine and the minerals Ca, P, Mg and S. Rumen degradability of protein and NDF and intestine digestibility of protein in rape, turnip rape and pea will be analysed with the insacco method. For pea, also the rumen degradability of starch will be analysed with the insacco method. Content of fat and protein, rumen degradability and intestine digestibility of protein will be determined in samples from both expeller cake and entire seed from rape and turnipe rape. Glucosinolate concentration will be analyzed in rape and turnipe rape, while tannins concentration will be analyzed in pea. Samples will be analysed according with the methods used in the Nordic Feed Evaluation System.

According to hypothesis 1, the results from the different quality parameters will be evaluated on the basis of published values and former feeding trials with conventionally grown rape, turnip rape and pea. Quality-parameters of significance for the use of crops in the production of concentrate for ruminants and poultry will be prioritized.

According to hypothesis 2, the results from the different quality parameters will be evaluated together with climatic factors and different nutrient supply in WP 3.

Task 2. Quality of organic oil for human consumption

There is a growing market for use of oil for human consumption. Since environmental factors play a role in a plant's production of secondary metabolites, it is hypothesised that an organic agricultural production system would increase phytochemical levels. Oils from seeds in this trial will be screened according to food quality markers. The oils from rapeseed will be processed at 'Askim Frukt-og bærpresseri' by 'Norsk Matraps' and Matforsk.

Hypothesis 1: There is a variation of total fat content and a variation of fatty acid profile whenever they are grown organic or conventional depending of the growing place.
Hypothesis 2: There is a variation of phytosterols whenever they are grown organic or conventional.
Hypothesis 3: There is a variation of glucosinolates in seed and isothiocyanates in oil whenever they are grown organic or conventional.
Hypothesis 4: There is a variation of phenolic compounds and antioxidant capacity in seed and oil whenever the varieties are grown organic or conventional.

Methods

Samples for analysis of organically and conventionally grown rapeseed oils will be collected from experiments in WP 3 and the Biodiesel project, respectively.

Chromatographic techniques will be used for detection on specific compounds. Liquid chromatography and gas chromatography coupled to mass spectrophotometric detector will be the most used analysing instruments. Matforsk has broad expertice and equipments for performing analysis of fatty acids, volatile compounds, phenolics, glucosinolates, different antioxidants and lipid oxidation products. Phytosterol analysis is built up in the current year in another project. Scavenging effects on (1,1-diphenyl-2-picrylhydrazyl) DPPH radical will be used for antioxidant capacity measurements.

5 Project organisation and management

The Norwegian Institute for Agricultural and Environmental Research (Bioforsk) Organic Food and Farming Division is responsible for the project, while Head of department Dr. Ragnar Eltun Bioforsk Arable Crop Division, will be the leader and co-ordinator. He has long experience as project leader of several organic farming projects funded by the Research Council of Norway (NRC). At present he heads the NRC programme "Organic cropping systems for higher and more stable cereal yields".

The project will be organised in five work packages (WP's) as follows:

WP1. Mapping of potential area for use of winter rape and winter turnip rape in Norway.

Responsible: Prof. Dr. Arne Skjelvåg, The Norwegian University of Life Science (UMB), Department of Plant and Environmental Research (IPM)

Other participating researchers:
PhD student/post doc Anne Kari Bergjord, Bioforsk Grassland and Landscape Division
Senior Researcher Dr. Ole Einar Tveito, Norwegian Meteorological Institute (met.no)
Scientific adviser Inge Bjørdal, Norwegian Institute of Land Inventory (NIJOS)

WP 2. Minimisation of problems with volunteers in spring turnip rape
Responsible: Senior Researcher Dr. Kirsten Semb Tørresen, Bioforsk Plant Health and Plant Protection Division
Other participating researchers:
PhD student/post doc Therese With Berge

WP 3. Cultivation practices for nutrient supply of oilseed crops
Responsible: Head of department, Dr. Ragnar Eltun, Bioforsk Arable Crop Division
Other participating researchers:
Senior Researcher Dr. Maria Stenberg, SLU, Department of soil Science
Senor Researcher Dr. Mauritz Åssveen, Bioforsk Arable Crop Division
Senior Researcher Unni Abrahamsen, Bioforsk Arable Crop Division

WP 4. Quality for feed and food
Responsible: Researcher Britt Ingeborg Foseide Henriksen, Bioforsk, Organic Food and Farming Division
Other participating researchers:
Senior Researcher Dr. Egil Prestløkken, 'Fellekjøpet Fôrutvikling'
Senior Researcher Dr. Gjermund Vogt, Matforsk

The project will have a project group composed of the participating researchers, and representatives from the participating companies 'Fellskjøpet Fôrutvikling', 'TINE produsentrådgivning' and 'Norsk Matraps AB'.

Bioforsk Organic Food and farming Division is a centre of expertise on organic agriculture in Norway and has solid competence within the field of fodder quality and nutrition of ruminants and poultry in organic farming. Bioforsk Arable Crop Division has a leading role within the Norwegian research on both conventional and organic cultivation of grains, oilseeds and protein crops. The Arable Crop division is also participating in the research project "Alternative high protein crop for the fodder industries" led by the Department of Animal and Aquacultural Sciences, UMB. Bioforsk is through this project part of a network of researchers working with the cultivation and quality of high-protein crops. Bioforsk Plant Health and Plant Protection Division has a leading role within research on weed biology and weed control in conventional and organic agriculture in Norway.

Dr. A. O. Skjelvåg and his group with representatives from IPM, Bioforsk, met.no and NIJOS has leading expertise in modelling of plant growth under Nordic conditions. His present PhD student A. K. Bergjord will have a part time post doc job in the project after finishing her studies in 2007.

'Felleskjøpet Fôrutvikling' which contribute to the project through collaboration with Bioforsk on the plant analysis in WP 4, is the leading producer of concentrates in Norway. Thus, it also has solid expertise on the need for raw materials and their quality in concentrate production. 'TINE produsentrådgivning' has a solid competence in the use of various fodder stuffs and feed planning for ruminants. 'Norsk Matraps AB' is the first company producing edible oil from rape in Norway, and they have had considerable success with their brand Odelia oil.

6 International co-operation

Among the Nordic countries which are the most actual co-operatiors in this project, it is only at SLU that they have ongoing research in organic cropping of oilseed crops. Experience from their project "Oljeväkster i ekologisk odling och mjölkproduktion: odlingsstratgier och användning til mjölkkor som ersätning för konventionella proteinfodermedel. Delprojekt 2: Kväveförsorjning vid ekologisk odling av höstraps efterföljt av höst- och vårvete" will be very usefull in the present project and SLU, Department of Soil Science, Division of Precision Agriculture, Skara, will be a partner in the project. Senior researcher Maria Stenberg will join the project group and be responsible for experiments at Lanna Research Station.

7 Progressplan – milestones

<u>Deliverables:</u>

Oral presentations/posters of the results from the WP's at national and international workshops/congresses throughout the project period.

WP 1 Manuscript on 'Climatic limitations for winter oilseed cropping in Norway' to be published in an international reviewed journal.
Maps on electronic medium or paper showing area for cropping of winter rape and winter turnip rape in Norway.

WP 2 Manuscript on 'Secondary dormancy in spring turnip rape' to be published in an

International reviewed journal.
Manuscript on ‘Management of volunteer spring turnip rape in organic farming’ to be published as a national paper/international congress.

WP 3 Manuscript on ‘Nutrient supply in organic oilseed cropping under northern growing conditions’ to be published in an international reviewed journal.
Report on ‘Camelina – an actual oilseed crop in Norwegian organic farming?’ to be published in a national paper.

WP 4 Manuscript on ‘Quality of organic grown protein crops for livestock concentrates’ to be published in an international reviewed journal.
Manuscript on ‘Chemical characteristics of organic versus conventional grown rapeseed oil’ to be published in an international reviewed journal.

Milestones:

WP 1 Phenological registrations in winter rape and winter turnip rape performed in variety trials at Kvithamar, Apelsvoll and Vollebekk (August 2006/June 2007, August 2007/June 2008, August 2008/June 2009).
Pot experiments on frost tolerance performed (winter 2007/2008).
Preliminary results presented (autumn 2009)
Paper submitted for publication (autumn 2010)
Maps of areas for winter oilseed crops (winter 2009/2010)

WP 2 Laboratory studies on induction/potential of secondary dormancy in spring turnip rape performed (September-October 2006-2008)
Field trials with management techniques established (autumn 2006-2009)
Preliminary results presented (2008-2009)
Paper submitted for publication (autumn 2010)

WP 3 Field experiments on nutrient supply in spring turnip rape and camelina established (2007 – 2009)
Field experiments on nutrient supply in winter rape and winter turnip rape established (August 2006 – 2008)
Preliminary results presented (2008 - 2009)
Paper submitted for publication (2010)

WP 4 Chemical analysis of protein feed composition and feed quality (autumn 2007 and 2008)
Preliminary results of protein feed quality presented for ‘Felleskjøpet Fôrutvikling’ ’TINE produsentrådgivning’ and farmers (2008 and 2009)
Paper on protein feed quality submitted for publication (2010)
Chemical analysis of edible oil (autumn 2007 and 2008)
Preliminary results of edible oil quality presented for ‘Norsk Matraps AB’(2008 and 2009)
Paper on edible oil quality submitted for publication (2010)

8 Costs incurred by each research performing partner

1000 NOK

Partner	2006	2007	2008	2009	2010	Total
UMB, IPM (WP 1*)						
Personal and indirect costs	130	290	340	330	190	1295
Equipment	5	10				
Other costs	10	25	25	25	20	105
Total	**145**	**325**	**365**	**355**	**210**	**1400**
Bioforsk Plant Health (WP 2)**						
Personal and indirect costs	135	295	270	205	130	1035
Equipment	5	10	5			20
Other costs	30	70	50	25	20	195
Total	**170**	**375**	**325**	**230**	**150**	**1250**
Bioforsk Arable Crop (WP 3*)**						
Personal and indirect costs	135	465	685	760	325	2370
Equipment	5	20				25
Other costs	10	35	35	35	25	140
Total	**150**	**520**	**720**	**795**	**350**	**2535**

Bioforsk Organic Food (WP 4**)**						
Personal and indirect costs	70	350	350	375	175	1320
Equipment						
Other costs	30	200	200	150	25	605
Total	**100**	**550**	**550**	**525**	**200**	**1925**
Total	**565**	**1770**	**1960**	**1905**	**910**	**7110**

*Including Bioforsk Grassland and Landscape Division, NIJOS, met.no and SLU
**Including Bioforsk Arable Crop Division
***Including SLU and administration costs
****Including Matforsk

9 Financial contribution by partner

1000 NOK

Partner	2006	2007	2008	2009	2010	Total
'Felleskjøpet Fôrutvikling'		50	50	50		150
'TINE produsentrådgivning'		30	30	30	30	120
Research Council of Norway	565	1690	1880	1825	880	6840
Total	**565**	**1770**	**1960**	**1905**	**910**	**7110**

In addition 'Felleskjøpet Fôrutvikling' will calculate feed values in WP 4, Task 1, estimated to 20.000 NOK in 2006 and 30 000 NOK in 2007-2009. 'Norsk Matraps AB' will contribute by pressing of oil samples for WP 4, Task 3, estimated to 60 000 NOK in the years 2007-2009.

PART 2: Exploitation of results

10 Relevance for knowledge-building areas

The present announcement of research founding from the Research Council of Norway is focused on increased availability of organic food by involving the whole production chain. In this project, aiming at secure production of high-quality raw proteins for livestock concentrates and edible oil based on oilseed crops, we are working with two production chains based on oilseed 1) safe organic production of oilseed crops in Norway → presscake as source for livestock concentrate → high quality livestock concentrates → high quality livestock products and 2) safe organic production of oilseed crops → high quality edible oil → new edible oil products.

The knowledge built in the project will help to secure a safe and sound production of existing organic products (milk and meet) and new products like edible oil. Scientific tasks applied for, are of relevance within the Research Council's field of bioproduction and results obtained will be built into the common knowledge on oilseed crops and their usage among scientists and advisers, the concentrate industry, the edible oil industry, farmers and the public.

11 Importance to Norwegian industry

The project partners will gain first-hand knowledge on issues related to the quality of protein- and oil –rich crops like their cultivation and usage. With this new knowledge the feed industry 'Felleskjøpet Fôrutvikling' will be better prepared for the planning and production of high-quality concentrates and the dairy adviser 'TINE produsentrådgiving', and the farmers will get access to these new products. This is of immense importance for the further expansion of organic husbandry.

The project is expected to result in an economic growth in the concentrate-industry because plant proteins produced organically in Norway can compensate for costly fishmeal and imported, organically produced plant proteins. An increase in the domestic production of high-protein crops might also help to adjust the market for organic feed grains.

Conventional edible oil is currently produced on a commercial scale by 'Norsk Matraps AB'. This company is also interested in developing an organic brand of edible oil, and knowledge gained through this project will be of significant importance in this perspective.

12 Relevance for Innovation programmes

The project will be part of the " Food programme" within the Norwegian Research Council. It will secure a competitive organic production of plant proteins for concentrates and give the base for new products like edible oil. Thus, it will contribute to the further development of organic agriculture in Norway. The project covers priorities concerning innovation, economic growth and cost-efficiency, which are commonly asked for by the contracting parties in the Agricultural agreement. More specific, it also covers priorities regarding development and cultivation of species/cultivars adapted to the nutritional need for various animals, which are of interest in the field of grain production. The project also falls within the research tasks prioritized in the Norwegian Research Council Report 2004: “Priorities of research on organic production and sales” where knowledge on nutritional aspects of domestic production of protein-rich crops is focused upon. The research tasks covered by the project also have a high strategic priority in Bioforsk and the co-operating institutions.

13 Environmental impact

In organic agriculture, genuine interest lies in the protection of the environment, derived through nutrient recycling, no use of pesticides, reduced transportation needs and good animal welfare. In this respect, the project will have a positive effect on the environment. Besides introduction of organic oilseed crops will give environmental benefits like better crop rotation in cereal dominated cropping systems and preservation of soil and nutrients by increased use of winter crops.

14 Information and dissemination of results

Each WP leader will be responsible for information about the work through newspapers, radio and television, web sites and meetings for farmers and extension officers. The scientific results will be published in international proceedings and journals.

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