IENICA

REPORT OF THE STATE OF FINLAND
FORMING PART OF THE IENICA PROJECT

IENICA is a project funded under the FAIR programme
by DG XII of the European Commission

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Plant Production Research

Crops and Soil

31600 Jokioinen

Finland

Acknowledgement of EC funding

IENICA – An Interactive European Network for Industrial Crops and their Applications, was a project funded by DGXII of the European Commission under the FAIR programme. The project began in February 1997 and was funded for three years.

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Preface

This report is a country study of Finland forming part of the IENICA (Interactive European Network for Industrial Crops and their Applications) project.

This report was prepared by Mrs. *Kristiina Antonius-Klemola* and Mrs. *Mia Sahramaa* from the Agricultural Research Centre of Finland (MTT). More information about the Finnish country report is available from Mia Sahramaa. The report was mainly compiled by contacting various organisations and companies and collecting information from them. We acknowledge numerous people for their kindness providing information and making writing of this report possible.

Jokioinen, Finland, November 1998

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Executive Summary

The objectives of this report are to document the state of knowledge on industrial crops and crop related processes, markets and uses of industrial crops and their products in Finland.

It has been estimated that about 1 million hectares of arable land will be set aside from food production in Finland before the end of this century. If most of this land is abandoned, the consequences for employment in and development of rural areas will be detrimental. The overproduction of food crops has directed research efforts towards various non-food utilisation of either traditional crops and new introduced species.

Climate conditions are decisive for crop production in Finland. Cultivation of wheat and oil-seed plants is restricted to southern Finland while barley, oats, grasses and potatoes can be cultivated in most parts of the country. The shorter growing season brings considerably lower yields than for central European countries. For the majority of field crops, the producer prices do not cover the costs of production. The EU subsidy policy and realization of Agenda 2000 will largely determine which crops are profitable for the grower and are thus chosen for cultivation in the future.

1. Oil crops. The most cultivated oil crop is spring turnip rape in Finland. Small to medium scale production of industrial products from oil crops already exists in Finland and the amount of industrial applications is slowly growing. The industrial products include lubricants, hydraulic oils, bio-fixers for plant protection chemicals as well as wood protectants and anti-rust oils. Pharmaceutical products are under development, and the paint industry is interested in developing new, more environmentally friendly products based on vegetable oils. The amount of available raw material and the domestic markets are generally too small for large scale industry

to specialise in the technical uses of oil crops. Many of the larger companies are likely to continue having both food and non-food applications in their product range.

2. **Fibre crops**. In recent years Finland has been importing short fibre raw material (birch) for making pulp and paper. Production of crops which could replace short fibre wood cellulose are an interesting new group of plants. If the processing can be organised, the cultivation of such crops could take up a large part of the available surplus land in the future. The greatest interest at present is in reed canary grass, which gives relatively high biomass and fibre yields in the Finnish climate. In 1998, reed canary grass was cultivated experimentally on 600 ha, but there is no market for it in the industrial sector to date. The main obstacles are economical and further research and demonstration work are needed.

The cultivation of hemp was rediscovered in Finland only a couple of years ago. The cultivation methodology in our conditions is not yet well established. At present industrial processing of hemp fibres is under development. Technical uses, such as thermal insulation, are apparently the best potential applications. Small scale industry exists for processing flax fibres. It is mainly specialised in manufacturing textiles and other products from organically cultivated raw material. The use of fibres which are obtained as by-products from linseed cultivation is investigated. The potential applications include, for example, reinforced composites and growth substances.

3. Carbohydrate crops. Starch is the most important industrial crop product in Finland, and the paper industry will continue using it. Northern growing conditions are especially favourable for barley, which contains here unusually high amounts of starch. The potato starch quota and EU subsidy policy are the most important factors determining the amounts of production. The strengths of the Finnish starch industry are highly developed processing methodology and good quality raw materials. Finland is one of the leading countries considering the technological know-how about the use of starch products in the paper industry. Active research is considerable, and there are good facilities for performing this research.

The production of starch based biodegradable polymers has been intensively studied and practical applications have been developed, some of which are now in a pilot phase. New potential products have also been developed and e.g. the use of poly(lactic acid) in the production of biodegradable polymers has been studied. The future of such products is, however, very much dependent on the development of common infrastructure, legislation and political decisions.

4. Crops with specialist uses. Several aromatic plants cultured or recently domesticated in Finland contain highly bioactive compounds. The application of these compounds in natural health products or in green chemicals including pharmaceuticals, preservatives and biopesticides are studied. In the production of herbs, Finland has the advantage of a non-polluted environment, the amounts of heavy metals are considerably lower than in many other European countries. In addition, weather conditions inhibit the growth of many pests and disease organisms, which is a benefit for the organic production of herbs. The knowledge of cultivation and processing methods is clearly at an expert level in such areas that the Finnish producers have specialised in. However, natural health products form a very large and diverse product group, which is still developing and a lot of research is still needed. The lack of co-ordination between numerous different small projects seems to be a particular problem in this area. Furthermore, the market demand for such products is limited even in central Europe, and therefore the cultivation area required in the future production of specialist plants is probably going to be well below that for carbohydrate and fibre crops. In spite of the relatively small cultivation area of crops with specialist use, the economical value of such crops can be high.

Agriculture in Finland

Finland is a republic which is situated in northern Europe, between the 60th and 70th latitudes bordering Sweden, Norway and Russia. Finland became a member of European Union in the beginning of 1995. The population of Finland is about 5,1 million, which is only 16 inhabitants per square km. Gross domestic product of agriculture have been decreasing in recent years being 1,3 % at this moment. Today only 5 % of labour force works in agricultural sector, when in 1980 the amount was over 10 %. Finnish agriculture is mainly based on family farms and in 1998 private individuals owned 80 % of all farms. Number of farms is now 140 000 (90 000 active farms), whereas it was 225 000 fifteen years ago. The amount of farms is still decreasing. Main reasons for that are high production costs and low prices of agricultural products. The average area of arable land per farm has increased slowly from 10,96 ha to 15,84 ha in 1980-1996.

Total land area of Finland is 337 000 square km of which 59 % is forest, 20 % waste land and peat land, 9 % lakes, 8 % arable land and 4 % built area. Finland is 1100 km long in south-north direction. The climatic conditions in various parts of the country vary considerably. In Southern Finland, the growing season is 170 days, but in north it is only 100 days. There is a lot of variation in the effective temperature sum, too: in the south it is 1300 and in the north 500 degree days. Precipitation during the growing season is usually 200-500 mm.

In 1996 the total amount of arable land was 2,6 million hectare of which 2,1million hector was cultivated. Most of the arable land (42 %) is used for growing cereals, especially barley and oats and for grass cultivation (27 %). The rest of the land is used for growing oil plants (2 %), sugar-beets (1 %) and potatoes (1%). The amount of fallow field (7 %) and other land (18 %) is also rather high. Cultivation of wheat and oil-seed plants is restricted to Southern Finland meanwhile barley, oats, grasses and potatoes can be cultivated in most parts of the country. Animal husbandry, especially milk production is the most profitable production form in most parts of the country. The shorter growing season brings about considerably lower yield levels of the field crop species than what is case in the Central European countries. For example in 1996 the annual yield of barley was 3430 kg/ha, oats 3370 kg/ha, wheat 4080 kg/ha, rye 2460 kg/ha, sugar-beets 25840 kg/ha and oil plants 1450 kg/ha.

Research and development of non food plant production started in late 80's. Paper industry uses starch, which is the most important commercial non food product in Finland. Development of other non food products is going on and most promising species like reed canary grass, hemp, linseed and some herbal species are now in research and pilot stage. Production of non food plants could be one alternative for Finnish farmers, and cultivation of them may also help slowing down the depopulation from rural areas of Finland. The main bottleneck in non food-production is processing and commercial use of new products. Further research and demonstration work is needed to make the production economically profitable.

More information about agriculture in Finland is available at:

http://www.finfood.fi/kartta.html (Agrifacts 1999)
http://www.mtt.fi/english/ (Agricultural Research Centre of Finland)
http://www.mmm.fi (Ministry of Agriculture)
http://agronet.fi/english.html (Agriculture in general..)

1.1 Science and technology

1.1.i Oil crops

Camelina (*Camelina sativa* L.)

A research group in Finland is investigating cultivation methods and comparing cultivars as a part of an EC funded project (DG VI FIL3, Contract no AIR 3 CT94 2178), which is co-ordinated from Denmark. Preliminary results have shown, that *Camelina* plants (false flax) can tolerate Finnish winter conditions well, and they yield up to 2.5 tons of seeds per hectare.

Linseed (*Linum usitatissimum* L.)

In the beginning of 90's, the research and development work for linseed and fibre flax started with a real contribution in Finland. R & D work is mainly done in the University of Helsinki, Agricultural Research Centre of Finland and Agropolis Ltd.

Linseed is grown only in southern Finland (between latitudes 60°N and 62°N). Nitrogen fertiliser for linseed is 40-50 kg/ha depending on soil type and the recommended seeding rate is 750-800 viable seeds/m^2. When the plant stand is about 5 cm high, a herbicide treatment against dicotyledonous weed species is usually necessary. The growth period of the domestic cv. Helmi is on average 110 days and non-domestic cultivars mature from one or two weeks later. Harvesting can be done by using commercial combine harvester, but to avoid problems during harvest, the cutting blade should be sharp and the linseed plant stand should not be lodged (Salo and Sankari, 1998a; Pahkala, 1998). The first Finnish linseed cv. Helmi, was registered in 1993 and this early and high yielding cultivar is preferred in Finnish conditions. Breeding work is still continuing at the Boreal Plant Breeding company in order to increase yield and change fatty acid composition (Salo, 1998). In addition to natural health products and animal fodder, medical products are under development. Non-food products include wood protectants, anti rust oils and raw materials in the paint industry. In general, the industry is interested in developing new, more environmental friendly products, such as binders based on linseed and other vegetable oils.

Spring turnip rape (*Brassica campestris* L.)

Spring turnip rape is the most common oilseed crop in Finland. It is mainly cultivated between the latitudes 60˚N and 62˚N, and sometimes up to 63˚N on the coast. All cultivars are 00 -type, which means that they contain low levels of both erucic acid and glucosinolates. The recommended sowing rate is 250-350 viable seeds/m^2, and fertiliser rate is 70-120 N kg/ha, 0-40 P kg/ha, 0-90 K kg/ha. Chemical treatment is required to control flea beetles (*Phyllotreta undula*) and blossom beetles (*Meligethes aeneus*). Yield levels in the official variety tests have been 1.9-2.5 t/ha depending on cultivar and cropping zone (Pahkala, 1998; Salo and Sankari, 1998b).

Spring rape (*Brassica napus* L.)

Spring rape is a minor oil crop in Finland. Its cultivation area is under 5% of the total area under oil seed production. It is grown only in the most southern parts of Finland. All cultivars are 00 -type. The recommended sowing rate is 300 viable seeds/m^2, and fertiliser rate is 110-130 N kg/ha, 0-40 P kg/ha and 0-90 K kg/ha. Chemical treatment is required to control flea beetles (*Phyllotreta undula*) and blossom beetles (*Meligethes aeneus*). Spring rape matures very late in Finland. Yield levels in the official variety tests have been 2.2-2.5 t/ha depending on cultivar (Pahkala, 1998; Salo and Sankari, 1998c).

Most of the seed yield is used by the domestic food processing industry (oil) and after pressing, the meal fraction is processed into feed for livestock. The industrial non-food applications include:

- for de-inking recycling paper: fatty acid based synthetic and semi-synthetic collectors for flotation and dispersants for washing (Raisio Chemicals)
- lubricants, hydraulic oils (BioSafe, Raisio Chemicals)
- turnip rape oil based bio-fixer, which enhances the efficiency of plant protection chemicals (Biokiinnite, Mildola)

<u>1.1.ii Fibre crops</u>

Reed canary grass (*Phalaris arundinacea* L.)

Reed canary grass has been bred for forage purposes in 1970's in Finland, but it was abandoned mainly because of its low palatability and high levels of various types of alkaloids. New non-domestic forage varieties with low alkaloid levels have now been developed, so reed canary grass could be an alternative also in Finnish forage production. Non-food applications of reed canary grass have been studied intensively from the beginning of 90's in the Agricultural Research Centre of Finland.

Reed canary grass is a native, perennial grass species, which can be cultivated even in the north, up to latitude 67˚N. Plant stands of reed canary grass are high, dense and productive in biomass, and it has shown to be the most promising plant for short fibre raw material of the field crops studied in the Agricultural Research Centre in Finland (Pahkala, 1997). Harvesting methods have been studied at Agricultural Engineering Research (MTT/Vakola) and at the Technical Research Centre of Finland (VTT). TTS-Work Efficiency Institute and Jaakko Pöyry Ltd. have made production cost calculations.

A delayed harvest system has been developed for reed canary grass: the crop is left in the field for the winter time and harvested the following spring. In that time the moisture content of the grass is usually under 15%, and no drying is required. The recommended sowing rate is 800-1000 viable seeds/m^2 (7-10 kg/ha). Seed is not yet produced domestically and foreign seed is expensive. Nitrogen fertilization is 70-100 kg/ha depending on soil type.

biomass yield of forage cultivars studied in Finland has been approximately 7-10 t/ha depending on the age of the plant stand and amount of fertilizers used. The development of cultivars, especially for non-food production has started in 1994, and new potential cultivars can yield over 10 t/ha (Sahramaa, 1998), which will increase considerably the production economics of the crop. Diseases are not yet a problem in Finland, but in recent years some pests such as leafhoppers (*Balclutha punctata*) and gall midges (genus *Mayetiola*) have caused damage to reed canary grass cultivations (Vasarainen, 1997).

Pulping of reed canary grass has been studied quite intensively in Finland in recent years. The following pulping methods have been used: kraft (sulphate) process, phospate pulping, IDE-process and MILOX method. Chempolis Ltd. is using and developing acid (HCOOH) based pulping technology for grasses and pulping of reed canary grass has been researched in the laboratory and on a pilot scale (Rousu, 1998).

Fibre flax (*Linum usitatissimum* L.)

Cultivation and processing of flax fibre has been rapidly developing in Finland during the last few years. Production of a good quality fibre crop requires a dense and even plant stand. In order to achieve such a plant stand, 2000-2200 viable seeds are required/m^2 (100-130 kg/ha). Fertiliser rates are 0-40 N kg/ha, 30-40 P kg/ha and 50-70 K kg/ha. A herbicide treatment (Glean 20 DF, Basagran 480) is usually needed. In the ecological cultivation method weeds are removed mechanically. Pest or diseases have not been found to cause any problems so far. Stem yield of flax has ranged from 3 t/ha to 10 t/ha depending on experimental site and cultivar (Pahkala et al., 1994). The crop is harvested in the beginning of August either by pulling or cutting and flax stems are then left for field retting for 4-6 weeks. (Salo and Sankari, 1998d; H. Sankari, Agricultural Research Centre of Finland, personal communication, Savikurki, 1994).

A new harvesting method, which is mainly suitable for harvesting fibre for technical use (insulation materials and other non-woven products), is being developed in Finland. In the new dry-line-method plants are harvested in springtime during March-May. This is possible because flax plants are typically winter standing, and stems are stored in the snow during the whole winter without damage or contamination. Harvesting during the driest period of the year enables avoiding problems such as high drying cost and difficult working conditions, which is usually the case during cold and rainy autumn (Pasila, 1998).

At present the only industrial product manufactured from flax fibre in Finland is textile, including speciality products from ecologically cultivated flax. Several new materials made of short fibres of flax and linseed are under development. These new innovations include insulation materials for ecological building practices and reinforced composites, which could replace many plastic components. Further, commercial growth substrates for mushroom and vegetable cultivation can be replaced by using these short fibre materials.

Fibre hemp (*Cannabis sativa* L.)

year later. Favourable EU agricultural policy has increased the interest for cultivation of hemp. In 1996 the cultivation area was 2 hectares, in 1997 74 hectares, and in 1998 the sowing area increased to almost 1200 hectares. Hemp has been earlier grown in Finland, but domestic cultivars (landraces) are no longer available. The earlier experience of hemp cultivation is decades old, and therefore cultivation methods for new cultivars are still under development.

Seeds can be sown by using commercial machinery. The recommended seeding rate is 250 viable seeds/m^2 (40-60 kg/ha), and the amount of nitrogen fertiliser is 70-120 kg/ha. Domestic seed production of the existing foreign cultivars of hemp is not possible and the sowing seed is very expensive. A sufficient stand density is required to prevent stems from growing too thick. Thick stems are difficult to harvest mechanically, and the amount of total fibre yield is lower. High hemp plant stands prevent weeds growing and therefore herbicides are not necessary. Harmful pests for hemp have not been observed in Finland, but grey mould (*Botrytis cinerea*) and rot (*Sclerotinia sclerotiorum*) has occurred especially in rainy summers.

The short growing period is the primary factor limiting the cultivation of non-domestic fibre hemp cultivars in Finland. According to the EU regulations, fibre hemp is not allowed to be harvested before half the seed is formed. Therefore, early cultivars were harvested as late as on 15 September at the Agricultural Research Centre in Jokioinen (61˚N), and 25 September at the North Ostrobothnia Research station (65˚N) in 1997. At this time of year, the relative air humidity is very high, and hemp biomass still contains 60-70% of water and artificial drying is needed. If harvesting could be carried out in the following spring, the moisture content of dry hemp stems would be under 15 %. However, the spring harvesting technology is still under development and hemp biomass quality is unknown at that time. Furthermore, this delayed harvest method is not yet accepted in the present EU regulations.

The experiments carried out at the Agricultural Research Centre in Jokioinen (1995-1997) resulted in average stem yields from 4.7 to 7.5 t/ha depending on cultivar and year. Yielding capacity of hemp has been reported to be higher in other European countries. Hemp stem yields would have probably been higher in Finland, if it had been sown in lighter soils. Increasing total stem yield will be one of the first tasks of the plant production research in Finland.

Another problem in hemp production is lack of processing industry in Finland. At present only one rope maker uses small amounts of domestic hemp fibre (Juha Alho). Other uses of hemp fibre are under development, for example, at the University of Helsinki, Department of Agricultural Engineering and Household Technology. Most potential applications are production of reinforced composites and thermal insulation materials, which have already been investigated to some extent. If new early blooming cultivars come onto the market, production of hemp seed will be possible and seed oil could be used for oil-based coatings. (Sources: Sankari, 1995, -, 1997, -, 1998; H.

Forestry, personal communication).

Nettle (*Urtica dioica* L.)
Cultivation methods including ecological cultivation of nettle have been investigated for several years in Finland. Production of nettle stems is now tested in cultivation trials. The amount of stem yield and quality, as well as the quality of the obtained fibre are included in the study (Bertalan Galambosi, Agricultural Research Centre of Finland, personal communication).

1.1.iii Carbohydrate crops

Barley (*Hordeum vulgare* L.)
Barley is the most cultivated cereal in Finland. It can be cultivated between the latitudes 60˚N and 64˚N, and in the coastal areas even further north. The recommended sowing rate is 450-500 viable seeds/m^2 and fertiliser rates given are 60-110 N kg/ha, 0-40 P kg/ha and 0-90 K kg/ha depending on soil type and cultivar. Fungicide treatment is profitable especially with disease susceptible cultivars. The crop is ready to harvest after a growth period of 86-98 days. Yield in the official variety testing has been 3.9-6.1 t/ha depending of cultivar and cropping zone.

Barley is mainly used as animal feed, but about 20% goes to industrial production (Vuorinen, 1998). At present the only industrial application of barley is use of starch in the paper industry. Barley as well as oat starch has been investigated as a potential raw material for biodegradable plastics at the Technical Research Centre of Finland (VTT), for example, for producing thermoplastic starch (Poutanen, 1997). The applications of barley and oat starch derived biopolymers are being investigated for paper/board coating, injection moulding, film and sheets, and fibres are investigated in another unit of VTT (Peltonen, 1997)

Potato (*Solanum tuberosum* L.)
Cultivation of starch potatoes has a long tradition in Finland. Since 1960's the production has been based on direct contracts made with the industry. Starch potatoes are cultivated in the southern parts of Finland. The required planting rate is 2.3-2.8 t/ha and fertiliser rates are 60-120 N kg/ha, 20-75 P kg/ha and 40-140 K kg/ha. Both early and late cultivars are available. Potato harvest starts usually in the middle of August and continues until the end of September. Producers have to store 50-70% of the yield on the farm for 1-2.5 months. Starch content of present cultivars is 16-20 % and yield 25-40 t/ha depending on the year and cultivation area.

Almost 40% of the total potato production is used in starch industry in Finland. The EC starch quota of Finland is 54 750 tonnes for the marketing years 1998/99-2000/01. Most of the starch is processed into various products utilised in the paper industry (Virolainen, 1997; Kangas et al., 1997). These products include (Raisio Chemicals, Starches):

the wire section, and enhance size stability. Starch can also be an independent of an integral part of the retention system

- Spray starches, which are mainly used on multi-layer liner and board machines
- Cationic surface size starches, which improve paper quality and printability
- Coating starches, which are used as binders in coating colours

Spring wheat and winter wheat (*Triticum aestivum* L.)

Spring wheat is cultivated in southern Finland, approximately between the latitudes 60˚N and 63˚N. The recommended sowing rate is 600-650 viable seeds/m^2, and fertiliser application is 50-120 N kg/ha, 0-40 P kg/ha and 0-90 K kg/ha. Fungicide treatment is occasionally necessary. Straw strengthening chemicals are seldom applied. The crop is harvested 101-105 days after sowing. The yield in the official variety tests has been 3.9-5.3 t/ha depending of cultivar and cropping zone (Salo and Kontturi, 1998a).

Winter wheat can be cultivated only in the most southern parts of Finland. The recommended time for sowing is late August or early September. Sowing rate is 500 viable seeds/m^2 and fertiliser rate is 30-40 N kg/ha, 0-40 P kg/ha and 0-90 K kg/ha in the autumn. Nitrogen fertilisation in spring is 80-130 kg/ha. Seed dressings or fungicide sprays are sometimes required to control winter damage. Fungicide treatments during summer are necessary occasionally. Straw strengthening chemicals are seldom applied. The crop is harvested after a growth time of 339-348 days. The yield level in the official variety tests has been 4.6-6.1 t/ha depending of cultivar and cropping zone (Salo and Kontturi, 1998b).

At present the only industrial application of wheat is the use of starch (Raisio Chemicals) in the paper industry. Future applications could include the production of biodegradable plastics. Polylactide, or poly(lactic acid), is technically strong and versatile thermoplastic polymer ultimately derived from annually renewable raw-materials, such as wheat. Biotechnical production from sugars using different, mainly *Lactobacillus* strains can produce almost pure L- or D-lactic acid, or racemate, or mixtures with the enantiomers at different ratios. The possible applications include:

- fibres and non-woven webs, which can be used in disposable diapers and other hygiene products
- blown films mainly for packaging such as wrapping and bags
- thermoforming to produce thin-walled but strong objects, such as plant pots
- extrusion coating of paper and board to be used as packaging materials

1.1.iv Crops with specialist uses

Sugar beet (*Beta vulgaris* L.)

acreage is sugar beet, it can be an important crop locally. Sugar beet cultivation is mainly in the most profitable growing areas in southern and south-western Finland. In the last few years the number of beet growers has fallen by a hundred per year and the released delivery rights have been divided among the old beet growers.

Sugar beet is sown in Finland during the first half of May and harvested in October. All beet are sown to stand and the aim is to get 90 000 beets/ha. Seed is always treated with Tiram and Tachigaren, and nowadays often with Gaucho or Curaterr, too. When treated seed is used, there is usually no need to control common pests like flea beetles (*Chaetocnema concinna*) or beet leaf bag (*Pegomyo hyoscyami*). Beet cyst nematode (*Heterodera schachtii*) and aphids are found only occasionally. The only notable disease, root brand, is satisfactorily controlled by Tachigaren. Rhitzomania has never been found in Finland. Three herbicide treatments are usually necessary to control weeds. Fertiliser rates are 80-150 N kg/ha, 10-80 P kg/ha and 5-455 K kg/ha.

Almost all beet growers have own a beet harvester and only 8% is harvested by contractor. The vegetation period is shorter than in any other country where sugar beet is grown and the mean yield, 33 t/ha is also lower compared to Central European countries. However, many other crops produce proportionally smaller yields in the Finnish climate and sugar content and extractability of sugar beet are on satisfactory level (Source: Raininko, 1997; Erjala, 1994).

Sugar beet is one of the several plant species accumulating glycinebetaine. Glycinebetaine content on dry matter varies 0.5 to 2%. The compound has several applications:

1) animal industry

- an additive in animal feed (swine industry)

2) pharmaceutical industry

- liver methionine metabolism
- homocystinuria

3) cosmetics industry

- skin lotions and hair care products

4) fermentation industry

- enhancement of glutamate production

5) crop production

- "insurance" against abiotic stresses (Jokinen and Virtanen, 1996).

Another application of sugar beet could be the production of biodegradable polymers.

Herbal species

production area of each species is very small, generally under one hectare. The total area under production of herbs, spices and medicinal plants was 1 894 hectares in 1997 (Official Statistics of Finland, 1997), most of which was caraway. The production of **caraway** (*Carum carvi* L.) is organised by contracts of a company (Arctic Taste Ltd.), which exports it to Central Europe. Other cultivated species include for example: *Echina purpurea* L., *Solidago virgaurea* L., *Perilla frutescens* L., *Mentha* sp., *Calendula officinalis* L., *Urtica dioica* L., *Agastache foeniculum* L., *Plantago lanceolata* L. and *Plantago major* L. as well as *Melissa officinalis* L. Field trials and cultivation experiments, which are partly funded by commercial companies (Hankintatukku Ltd, Finland; Bioforce AG, Switzerland) are performed at the research stations of the Finnish Agricultural Research Centre.

The current research on herbal plants was summarised by Bertalan Galambosi, research scientist and project leader, from the Agricultural Research Centre of Finland as follows:
The suitability of Central European cultivars for Finnish growing conditions are being tested in field trials for the following plant genera: *Origanum*, *Satureja*, *Thymus*, *Salvia*, *Valeriana*, *Dracocephalum*, *Achillea*, and *Levisticum*. Natural populations are collected and evaluated in several test locations for the following species: *Solidago virgaurea* L., *Hypericum perforatum* L. and *Hypericum maculatum* L. The quality of seed in ecological cultivation is tested for the following genera: *Matricaria*, *Achillea*, *Myrrhis*, *Hyssopus*, *Dracocephalum*, *Agastache*, *Levisticum* and *Angelica*. The possibility of using machinery in ecological seed production is investigated for the following genera: *Matricaria*, *Achillea*, *Agastache*, *Hyssopus*, *Viola* and *Angelica*. Vegetative propagation in ecological cultivation conditions is tested with *Mentha* species.The growth possibilities in Finnish conditions, cultivation methods and quality is investigated for the following pharmaceutical herbs: *Rhodiola rosea* L., *Myrica gale* L., *Gentiana lutea* L., *Anthoxanthum odoratum* L., *Artemisia abrotanum* L., *Cynara scolimus* L. and *Myrrhis odorata* L. The growth possibilities in Finnish conditions are investigated for the following new introductions in the following genera: *Acanthopanax*, *Ginseng*, *Althaea*, *Alchemilla*, *Cichorium*, *Inula*, *Chenopodium*.

An interesting example of the research is the development of cultivation methods for **sundew** (*Drosera* sp.), a plant which in natural growth conditions captures insects for protein. These plants contain several effective compounds, such as droseron, plumbagine, 7-methyl juglone as well as flavonoids and proteolytic enzyme (Galambosi and Galambosi, 1997; Rapcak and Galambosi, 1997). The producers of natural health products also have done some research on their own (non-public) on both cultivation and processing methodology (Arno Latvus, Hankintatukku Ltd., personal communication).

In addition of the production of dried herbs, the possibility of producing essential oils is investigated in Finland. The most studied and simple method to produce essential oils is steam distillation. During the last few years of the comeback of herbs, two semi-large distillation units have been made in Finland for experimental purposes. Most probably, bigger and more efficient distillers will be developed in the near future due to the interest in essential oil *greveolens* L.) are the best potential species either for seed production (caraway, dill), dry herb (mint, dill) or essential oil production (caraway, mint, crown dill). Several terpene and flavonoid compounds have been identified from these species and applications of the herb or oil for pharmaceuticals, cosmetics, food and feed additive in functional food, and as a pesticide, are currently studied in the Agricultural Research Centre (Marjo Keskitalo, Agricultural Research Centre of Finland, personal communication).

Tansy (*Tanacetum vulgare* L.)

Tansy is native to Eurasia and now widely distributed in the world. Tansy is well-adapted to the Finnish climate and is able to produce high yields of flowerheads. More than 100 volatile compounds, mostly terpenes, have been identified from the flowerhead of tansy. Several compounds of tansy are antimicrobial and pesticidal. Genetical, morphological and chemical differences of Finnish tansy germplasm were evaluated (Keskitalo et al., 1998a) and showed high variation. A micropropagation method for tansy is also now available to obtain vegetative clones from the most desirable chemotypes. The possibility to increase pesticidal activity of tansy by protoplast fusion with pyrethrum (*Tanacetum cinerariifolium* L.) resulted in the formation of fusion calli (Keskitalo et al., 1998b). The regeneration methods from protoplast derived -calli will be further studied. Overall, the demand for natural, environmentally benign pesticides is increasing.

Cataranthus (*Cataranthus rosaus* L.)

Cataranthus is originally a tropical plant, known as an ornamental in many European and American countries. A new cv. Petrus, has been registered at the University of Helsinki, Department of Plant Production. Preliminary studies have shown, that it can be grown in Finland year around in greenhouses, from April to October in non-heated plastic houses, and from June to September on open fields. Micropropagation has proved to be an efficient method for producing plant material in Finnish experiments (Alén and Jain, 1997), and the possibility of taking cuttings is being investigated.

The above-ground parts of cataranthus contain catharine and vindole alcaloids, which can be used in the biosynthesis of vinblastine and vinchritine. The plant contains very low amounts (0.0003%) of complete vinblastine. Vinblastine as well as vinchristine are substances which have been used for cancer medication. Today their half synthetic derivatives, such as vindesine and navelbine, are more important. At present, a research group at the University of Helsinki, Department of Plant Production is developing an economically profitable method for producing cataranthus in Finland. In addition they are trying to increase the alkaloid content of plants with the help of induced mutations and biotechnology. The group has already found a new and very efficient method for synthesising vinblastine, and now it is being optimised for large scale production (Source: Karita Alén, University of Helsinki, personal communication).

1.2. Industry

1.2.i Oil crops

Camelina

At present there is no industry in Finland which uses *Camelina* as a raw material.

Linseed

The amount of linseed oil used in non-food processing is not available. The technical applications of domestic linseed oil (wood protectives, anti-rust oils) are unmodified basic linseed oils. In addition, the paint industry uses different types of linseed oils, which are mainly imported due to lower prices of the raw material. The processing system for linseed oil is based on cold pressing in anaerobic conditions (Elixi Oil Ltd.).

Rape and turnip rape

Rape and turnip rape oils are pressed by two industrial companies in Finland, Raisio Group and Mildola. The pressing procedures in the two companies are somewhat different. Processes differ depending on end uses of the oil (food or non-food). The total oil yield in Finland is approximately 40 000 tonnes yearly and around 2 000 tonnes is used in technical applications (non-food) (Anon., 1997). The availability of raw material is not a problem (K.E. Lindén, Raisio Chemicals, personal communication).

Both natural and synthetic lubricants are produced. In the production of synthetic oils, the natural ester chains are elongated and calcium citrate is added. De-inking chemicals are produced from the fatty acids. The bio-fixer for plant protection chemicals is processed by mixing turnip rape seed oil with emulgators.

Examples of the import of raw oils (kg) for non-food purposes into Finland in 1997

soybean oil	100
groundnut oil	797
sun flower and safflower oil	12 297
palm oil	14 000
rape, turnip rape and mustard oil	718 527
linseed oil	247 334

Source: Foreign trade statistics, the board of customs, Finland

1.2.ii Fibre crops

Reed canary grass

At present there is no industry in Finland using reed canary grass as a raw material for pulp and paper.
Fibre content of reed canary grass is the same as for wood, about 50% of dry matter. Fibre length is similar or shorter than that of northern birch. About 90% of all chemical paper pulp is made using the **kraft (sulphate) process** in Finland, where the raw material is treated with a highly alkaline solution of NaOH and Na_2S. The kraft process has proved to be a possible method also in grass pulping (Paavilainen, 1996; Pahkala et al., 1997). In 1995, Finland was first in the world producing pulp in a pilot-scale from bleached reed canary grass. The pilot pulping was done at Tervakoski Ltd. and bleaching at Enso Research Centre. The pulp was made into paper on a pilot machine of the Finnish Pulp and Paper Research Institute. No runnability problems were encountered even with 70% reed canary grass. The remaining 30% of the fibre was long-fibre pine pulp. Based on these trials, birch pulp can be replaced by grass pulp in the fine paper furnish without affecting the properties of the coated fine paper (Pahkala et al., 1997).

In **phosphate pulping**, an alkaline cooking chemical, trisodium phosphate (Na_3PO_4), is used. In pulping of grass plants, anthraquinone is used as a catalytic agent and the cooking temperature is between 145-165˚C. Properties of pulps prepared using the phosphate method and soda method were similar (Janson et al., 1996). Pulping with organic solvents, such as alcohols, in different combinations with sodium hydroxide or sodium carbonate, has been studied for non-wood plants both in the laboratory and on a pilot scale. In the **IDE-process** (Backman et al.,1994) the raw material is first impregnated with sodium hydroxide and sodium carbonate at a temperature about 100˚C. In the second step, the depolymerisation stage, the raw material is subjected to ethanol-water solution at 140-190˚C. The **MILOX** pulping and bleaching method is based on formic acid and hydrogen peroxide. In the acid MILOX process silica remains in the pulp after cooking, but it is possible to dissolve it in alkaline H_2O_2 during the bleaching process (Seisto & Poppius- Levlin, 1995).
Chempolis Ltd. has developed nonwood pulping process for different reeds e.g. common reed, reed canary grass, sarkanda and straws (wheat and rice), which have been successfully researched in laboratory and pilot scales. The process uses **formic acid** (HCOOH) as a cooking chemical. The fibre line of the process is similar to other conventional pulp processes. It starts with cooking and follows with washing, screening and bleaching stages. The main differences are in the cooking chemicals and in their recovery system. The recovery comprises evaporation and distillation of the acid. The regenerated acid is circulated for cooking while the dissolved solid is dried. Lignin can further be used for processing in the chemical industry, or it can be burned in an ordinary power boiler. Pulp has been cooked in batch-type cooking reactors and further washed, screened and bleached. Formic acid based technology is especially suitable for high silicate consistent non-wood plants i.e. reeds and straw. The runnability of the stock has been tested in a Valmet high speed pilot paper machine. Reed canary grass based fine paper test

implemented with ordinary technology. Commercialization of the process to an industrial scale will start in 1999. The first mill is planned to be the size of a demonstration plant.

Fibre flax

The processing of flax fibre is a relatively new area in Finland. There is only one company (Norrholm Ltd.), which owns the whole set of machinery needed in the process. Flax fibres are spun in Almedahl spinning mill in Finland. Yarn is used in production of linen textiles (for example Jokipii Ltd.)

Hemp

The hemp processing industry is under development in Finland. In Helsinki, there is one hemp store, which imports all hemp made products from abroad (Rami Kiskola).

1.2.iii Carbohydrate crops

In 1997 industry used the following amounts of carbohydrate plants in non-food production, mainly in starch production: 261 590 tonnes of potatoes, 93 110 tonnes of wheat and 271 170 tonnes of barley (Balance Sheet for Food Commodities, 1997). According to Kari Nurmi (Raisio Chemicals, personal communication), the amount of potato used in the starch producing industry could probably increase to 500 000 tonnes only by repairing or replacing old machinery.

Finland is the only European country which does not have overproduction in starch. On the contrary, the present quota of potato starch (54 750 t/year until marketing year 2000/01) is much too small, and starch is imported to meet the needs of industry.

Examples of starch import (kg) into Finland in 1997

wheat starch	2 636 036
corn starch	13 189 879
potato starch	24 893 746
manioc starch	2 000
rice starch	362 368
inuline	11 248

Source: Foreign trade statistics, the board of customs, Finland

The technology of starch production and processing is well known in Finland. However, new synthesis routes are sought for starches, celluloses and rosin acids. In addition, genetic manipulations may generate new variaties, which would be more resistant to freezing and waterlogged growing conditions.

A technique to prepare cast films of starches was developed at VTT and film formation properties of barley, potato, oat and maize starches were investigated (Poutanen, 1997). Furthermore, the plasticization effect of glycerol was examined in the case of barley and potato starches. The results showed that starches have good film formation properties, but they are too hygroscopic and weak to be used in food packaging applications. Starch/PCL (polycaprolactone) blends could represent such applications. Starches, however, could find uses in applications where good gas barrier properties can be exploited, like improving stability of various foods.

The development status of other starch based biopolymers, bioplastics, dispersions and their applications is following (Peltonen, 1997):

- paper/board coating - pilot development
- injection moulding - production, pilot development
- films and sheets - development
- fibres (development)

When the starch based materials were introduced, a trade name was applied. The trade name COHPOL™ in now registered in Scandinavia and UK. Based on market analysis and interviews of potential customers the application areas chosen are: adhesives, biopolymers for mouldings, paper and board coating, tabletting experiments, controlled release materials, and paints (Peltonen, 1997).

Biodegradable polymers are also produced from polylactides, which have been intensively studied in Finland. As with other polymers, polylactide has little value as such. Only after addition of stabilisers, UV-inhibitors, plasticisers, fillers, lubricants and other additives does a polymer becomes a useful plastic (Selin, 1997). Processing technology has been developed for producing fibre and non-woven webs, blown films and extrusion coating for paper and board.

Typically, about twice the amount of feed grains are needed for one tonne production of PLA. In the case of sugar beet the ration is much higher 9:1. The estimated potential of 100 000 tonnes per year by 2005 PLA markets would translate into cultivation area needs of 20 000-40 000 ha in Europe, but varying according to the agricultural product selected (Selin, 1997).

Sugar beet

Sugar beet molasses are used as raw material applying a patented chromatographic separation method developed by Cultor Ltd. In the process, a complex mixture of chemicals can be separated into individual components based on their chemical and physical characteristics. The process is carried out in large columns filled with separation resin. Water is used to elute the molasses through the column system. At the outlet points the different compounds are collected as pure solutions. The compounds are concentrated and crystallised e.g. pure natural betaine. The amounts of Finnish sugar beet raw material is not enough for betaine production, and therefore supplementary crude betaine extract is imported. The purity of betaine depends on the use: the highest purity is required in the pharmaceutical and cosmetical applications. Products which are used to relief stress conditions of domestic animals (pigs, chickens) is the next highest in the purity level. The lowest purity requirements are associated with products for plant protection (Jokinen and Virtanen, 1996). The details of production capacity and the amounts of betaine production are not available. New applications for the betaine molecule are being investigated in the research division of Cultor Ltd. in co-operation with universities and research institutes.

The figures of **natural health products** are not registered and therefore the production volumes are not available. Because of limited demand of markets, the needs for raw materials in the industry are unlikely to increase dramatically. The effective compounds are extracted and processed into pharmaceuticals and health products mainly by the following Finnish companies: Hankintatukku, Vitabalans, Valioravinto and Frantsilan yrttitila.

Cataranthus

At present there is no industry in Finland which uses *Cataranthus* as a raw material.

1.3. Markets

<u>1.3.i Oil crops</u>

The annual area under oil crop cultivation (food and non-food are not registered separately) is 55 300 ha of turnip rape and rape, and 2 207 ha of linseed. The amount of turnip rape and rape used in industrial applications is around 2 000 tonnes. The amount of linseed raw material is not available. No other oil crops are cultivated in Finland, but some are imported for non-food production.

The turnip rape oil based bio-fixer, which enhances the efficiency of plant protection chemicals, is marketed in Finland. The sales of the product have been steadily increasing and the trend is expected to continue (Stefan Selen, Mildola Ltd., personal communication).

Vegetable oil based lubricants, hydraulic oils and de-inking chemicals (paper industry) are apparently easier to market than completely synthetic products, provided that the price is not higher (Karl-Erik Linden, Raisio Chemicals, personal communication). Production is based on direct contracts with the industry. The price of rape or turnip rape paid to the grower is the same whether the crop is used for food or non-food purposes. Because of the subsidy policy, turnip rape is less profitable compared with fodder barley in the A-subsidy area. The difference is however so small that if the value as a preceding crop in rotation is taken into account the result favours turnip rape. In the B, C1 and C2 areas turnip rape competes well with barley (Anon., 1997).

The total amount of linseed produced in Finland in 1997 is probably about 1 500 tonnes (calculated by multiplying the average ha production with the number of hectares in linseed cultivation). Accurate information about the markets and profitability of linseed production is not available. Both the production and markets are estimated to be growing slowly.

1.3.ii Fibre crops

Reed canary grass

In 1998, reed canary grass was cultivated experimentally on about 600 ha, but so far, there is no market for it in the industrial sector. The short fibre raw material for the Finnish pulp and paper industry is birch, for which domestic availability has been insufficient in recent years. Finland is importing yearly 6-11 milj. m^3 of birch, mainly from Russia. Grass pulp could replace imported birch, but investment in building new processing lines are needed, if the raw material is changed from birch to grass. At present, establishment of a new demonstration mill has not yet been realized. The price for producing reed canary grass pulp must not exceed the price of imported birch. Cultivation is profitable for a farmer if the price is about 0.40 FIM/kg. Production subsidies are also important factors to determine whether the production is profitable or not. According to Mela (1993), the amount of land used for reed canary grass fibre production would be about 100 000 hectares. One production line in a pulp mill would use the biomass yield from 30 000 hectares.

Fibre flax, fibre hemp

Total cultivation areas in 1997 were 994 hectares for flax and 74 hectares for hemp. Information about the amounts used in industrial production are not registered, and the future market situation is not known. According to Metti Salminen from the Agricultural Research Centre of Finland, conventionally grown fibre flax cannot compete with the major flax producing countries. Therefore, specialisation into organic flax production would be a good alternative (Salo, 1998).

1.3.iii Carbohydrate crops

The total areas (the proportion of non-food production is not available) under carbohydrate producing crops and total yields in 1997 were:

	Cultivation area, ha	total yield, tonnes
Wheat	124 000	464 100
Barley	533 400	2 003 500
Potatoes	40 900	754 100

At present there are no different price systems for wheat and barley, which are used for non-food purposes. However, the non-food price is most probably not higher than the price of fodder or bred grains. Cereals are generally less profitable than sugar beet or potatoes when the gross margins (Annexes) are compared.

In a study by Virolainen (1997) the production costs of starch potatoes were calculated for several sizes of production units and two different yield levels (30 and 40 t/ha). The calculations showed that compared with the price paid to the producer, none of the unit sizes, even with the higher yield levels, could cover the costs of production with the returns. Therefore, with the present product prices the various kinds of production subsidies are the most important factors determining whether the production is profitable or not. The study also suggested that starch potato production is competitive with grain production, especially at the higher yield level (40 t/ha), and if the farm co-operates by sharing machinery with another farm. In practice the required yield level can be achieved in the southern parts of Finland. However, comparisons of gross margins in the model calculations for 1995 (Anon., 1995) show that food potato production was clearly more profitable.

The most important user of starch is the **paper industry**. According to Kari Nurmi (Raisio Chemicals, personal communication) the paper industry is growing steadily approximately 2.6% per year, and the production of top quality papers somewhat faster, about 4% per year. Finland produces about 4% of the world's paper. However, because the production is specialised in quality paper, the use of chemicals is 10% of the total consumption in the world. Consequently the use of starch based products is also especially high in the paper industry.

According to Peltonen (1997) the commercialisation of **biodegradable polymers** is closely connected with the general development of the infrastructure and the related legislation and the political and other decisions made both at the national and the EU level. Waste management infrastructure is changing in different countries. Integrated solid waste management systems including composting of a source separated bio-waste are needed and commercialisation of biodegradable polymers. The estimation of market size and growth vary considerably in various market studies (Peltonen, 1997). The following estimates are based on existing studies and reports combined with opinions of potential customers and personnel of Primalco's Polymer unit.

The use of biodegradable plastics is predicted to grow fast in disposable packaging, hygiene, and sanitary products, paper and board coatings and laminations and disposable cutlery and dishes e.g. in fast food restaurants. The applications of biopolymers in various other end uses like adhesives for compostable products and 'eco-paints' will increase the market potential of the new developing materials.

The most promising markets for biodegradable products are European markets. The markets for degradable plastics are estimated to grow up to 150 000 t/a by the year 2000, the biodegradable plastics representing 60 % of the amount. The growth is estimated to continue and expected market size for biodegradable plastics in 2005 is 200 000 - 250 000 t/a in West Europe. The price estimation for industrial scale production is 3-5 $/kg. Starch based materials are forecast to represent 30-40% of the markets. The poly(lactic acid) biopolymers are forecast to take about half of the markets (Selin, 1997).

1.3.iv Crops with specialist uses

Sugar beet

According to Kyösti Raininko (Sugar Beet Research Institute) the sugar beet growing area was 33 000 ha in 1997. Production is controlled by a quota determined by EU administration. Information about the markets of glycinebetaine is not available. Mikkola (1997) compared the profitability of sugar beet production in 1994 and 1995, which was the first year of the EU membership of Finland. In this period the producer price of sugar beet decreased 21% compared with 1994, if the subsidies for the transition period are not taken into account. If the gradually decreasing subsidy for the transition period (1995-1999) is added to the prices the returns in 1995 varied from 0.1 FIM/kg loss to 0.03 FIM/kg profit (1 FIM = 0.167 ECU, 28.9.-98). In addition, when the area based subsidies were taken into account, the produces prices increased 0.05-0.07 FIM/kg. In the latter case the profits generally covered production costs.

In comparison with the contribution margins of the model calculations for 1997 (Annexes) sugar beet production is clearly competitive with cereal production. The same appears to be true for all other food or feed crops, with the exception of food potato.

Herbal species

The total area under production of seeds of herbal species and medicinal plants was 1 894 hectares in 1997, of which caraway covered the most (Official Statistics of Finland, 1997). Market value of natural health products production. Consumers consider the natural health products as luxury items, and the markets follow the general economic situation. Today the economical status is improving, and 'green ideas' as well as soft values seem to be gaining more support. Therefore, the markets for natural products are also increasing. However, the markets for such products in Finland are very limited in volume, and it is not profitable to base industrial production only on the domestic demand. Knowledge about herbal medication is not included in the education of doctors in Finland. The use of alternative products in the treatment of patients is thus very small compared with countries such as Germany and France. At present approximately 30% of Finnish production in this area is exported (Matti Kaarlas, chief of extraction processes and Arno Latvus, managing director, Hankintatukku Ltd., personal communication).

According to Marjo Keskitalo (Agricultural Research Centre of Finland, personal communication) thousands of hectares of arable land could be used in the production of speciality plants in Finland. Potential markets exist for several different products (green chemicals such as essential oils, pharmaceuticals, pesticides), provided the problems in the cultivation and production methodology are solved. A wholesale business (possibly a growers' co-operative) is needed in Finland to take care of the marketing and processing of alternative crops and crop products.

1.4. Environmental

In general, perennial plants used in non food -production usually improve the soil structure, when compared with monocropped cultivation of grain. Finnish weather conditions inhibit the growth of many pests and disease organisms, so the amount of agrochemicals needed is quite low. Finland has the advantage of a non-polluted environment.

The amounts of heavy metals are considerably lower than in many other European countries. Finnish national heavy metal regulations are generally rather tight. We have regulations for the upper limits for heavy metals in all fertiliser products, as well as in the sewage sludge and the agricultural land, where it is going to be used (Annexes). In the European Union there is no upper limit for cadmium in fertilisers. In Finland, cadmium load from phosphorus fertilisers on cultivated soils have decreased due to use of domestic, almost cadmium-free raw phosphate in the production of fertilisers. It is now lower than in any other OECD country. Since 1992, the use of mercury-containing pesticides has been prohibited in agriculture, and mercury is therefore no longer added to soils with seed dressings. The regulations for the upper limits of heavy metal loads to arable land limit the use of sewage sludge in agriculture (Mäkelä-Kurtto, 1998). In fact, the high content of phosphorous restricts the addition of sludge to low levels. The amounts and quality of sewage sludge are listed in the annexes.

1.4.i Oil crops

Camelina plants with weeds, herbicide treatments may be required. However, the effectiveness of mechanical harrowing is also being investigated.

Linseed is a modest plant, which requires low amounts of nitrogen. Herbicide treatment is always needed.

Rape and turnip rape are annual field crop plants, which require relatively high amounts of fertilisation. Pesticide treatments are always required to control infestations.

1.4.ii Fibre crops

Reed canary grass

Reed canary grass is drought and flooding tolerant and the amount of nitrogen fertiliser required per hectare is approximately 70 kg. Herbicide treatment may be required only in the year of establishment because reed canary grass has a slow and irregular germination of seed. As a perennial grass it can be harvested from the same field for as long as 10 years, which improves the soil structure and increases the organic content in the soil. Long-term cultivation of reed canary grass prevents soil erosion and nutrient leaching. Reed canary grass can also be used in peat production areas before or after peat production for nutrient uptake, water filtering or water evaporation.

Sewage sludge is suitable for cultivation of reed canary grass. Partala et al. (1997) investigated sewage sludge as a nutrient source for reed canary grass. Finnish sludge contains low amounts of heavy metals and the real limit for sludge use is phosphorus. The legal addition rate of sludge increases heavy metal loads only slightly to plant and soil. In experiments a high amount of sludge (illegal) only slightly increased the Pb concentration in shoots and roots which was caused by the increased soluble Pb concentration in the soil.

Fibre flax

Flax production is very environmental friendly in Finland. According to the growers, no fungicide treatments for seeds or no straw strengthening chemicals are needed in our conditions. The organic production methods for fibre flax in Finland are currently under development in a collaborative project (Agropolis Ltd. and Agricultural Research Centre).

Fibre hemp

Hemp cultivation needs relatively high amounts of nitrogen, but herbicides and pesticides are not needed. However, fungicides against moulds are needed in rainy summers.

1.4.iii Carbohydrate crops

Carbohydrate crop plants are annual (barley, wheat, potato) and therefore the field surface is covered for less than half of the year. To produce a good starch yield, a sufficient amount of nitrogen fertilisation is needed. The use of plant protection chemicals is not particularly prominent in the production of carbohydrate crops, although some treatments are usually needed.

The use of starch based products has been shown to reduce some of the waste water problems in the paper industry (Kari Nurmi, Raisio Chemicals, personal communication).

LCA/TCA (Live Cycle Analysis / Total Cost Assessment) has been applied to a case of producing 1000 baby diapers in order to be able to compare traditional plastic components and polylactide (biodegradable polymer) (Selin, 1997). The most important outcome of this study was the astonishingly small differences between the impacts of the traditional and the biodegradable diaper systems. In most scenarios is the polyolefin based diaper, which environmentally is somewhat preferable, but the results are not clear yet. Phases causing most impact to environment are agricultural production of raw materials and the fermentation of lactic acid (eutrophicative emissions and energy consumption). Cultivation results eutrophicative emissions caused by fertiliser and pesticide production and use. However, the production of biodegradable polymers is still young with several stages in their pre-commercial phase. Already, minor changes in the technology level may strongly affect the environmental impact of the system.

1.4.iv Crops with specialist uses

Sugar beet

The seeds of sugar beet are treated with plant protection chemicals before sowing. In order to control weeds, three herbicide treatments are usually necessary. The total use of pesticides has been decreasing since 1989. Placement of compound fertiliser, specially designed for sugar beet is an effective way to improve the utilisation of the fertiliser and decrease pollution of nutrients (Raininko, 1997).

The various **herb species** which are grown for the production of natural health products all have their own special cultivation methodology. However, to avoid any chemical residues in the yield, most of the cultivation is conducted according to ecological methods (no plant protection chemicals, no inorganic fertilisers).

2. BARRIERS TO PROGRESS

2.1. Scientific

2.1.i Oil Crops

Camelina

The main problem in the *Camelina* production experiments in Finland has been its weakness in competition against weeds. An efficient, and possibly environmental friendly, method of controlling weeds is needed to allow large scale production. In addition, industrial processing systems have not yet been developed.

Linseed

Linseed is cultivated only in southern Finland due to its requirement for a long growing period. Breeding for earlier cultivars with higher seed yield and better chemical properties is under way.

2.1.ii Fibre crops

Reed canary grass

Non-food use of reed canary grass requires a completely different quality compared with forage. Varieties developed especially for non food -purposes are not yet available, but are under development. Domestic seed production of reed canary grass is an economic necessity in the cultivation. At present, foreign seed is used, but domestic seed production is under development.

Fibre flax

Ecological cultivation is apparently the most advantageous form of flax production in Finland. However, in such cultivation weed control is usually problematic. Mechanical removal of weeds needs to be developed. Harvest methods can also be developed for unfavourable weather conditions, when field retting is not successful.

Fibre hemp

For fibre hemp, the cultivation methods, especially harvesting technology, are still under development. The present European cultivars are generally too late maturing, and give lower yields in our conditions.

2.1.iii Carbohydrate crops

Potato

The present starch potato cultivars give sufficient yields in southern Finland. New cultivars could be developed, for example with the use of gene manipulations, to withstand early frosts and sometimes waterlogged growing conditions.

Numerous herbal plants grow in natural conditions, but their efficient cultivation, as well as processing methods, still need to be developed. Unrealistic expectations of getting practically applicable results in a very limited time schedule from the present research programs have partly weakened the general opinion about the possibilities of new crops. It should be stressed that, in the case of a new plant species, the time needed to establish basic cultivation methods, processing, and marketing is long. Thus, significantly longer that the current 3-year long research programmes are needed, especially when new plant species are studied (Marjo Keskitalo, personal communication).

2.2 Technical issues

Reed canary grass

Techniques for cultivation, processing and pulp making of reed canary grass are quite advanced. In spite of the progress in recent years, production and utilization of grass pulp have not started. The reason for that is mainly economical, because a new grass pulping line requires investments. Furthermore, the availability and quality of raw material cannot yet be quaranteed. Composition of reed canary grass differs from wood; mineral content (ash, silica) is higher. High mineral content causes problems in pulping and recovery process. Pilot projects are still needed to demonstrate the whole chain of events from field to paper.

Reed canary grass, fibre flax, fibre hemp

The main barrier to greater production is almost total lack of fibre processing industry in Finland and high investment costs.

2.3 Environmental

The field rotation system may limit the amount of production of some non-food crops.

2.4 Legislative

Cultivation of **reed canary grass** for non-food purposes is not getting non-food subsidies from EU. The reason is that the EU has not approved reed canary grass as a non-food plant because fodder varieties are used in cultivation. However, there are no varieties developed especially for non-food production available at this moment.

The cultivation of **fibre hemp** is allowed only with certain varieties approved on the EU variety list. According to the EU regulations, fibre hemp is not allowed to be harvested before half of the seed is formed. A delayed harvest method would be more profitable in hemp production, but it is not yet accepted in the present EU regulations.

The production of **sugar beet** as well as **potato starch** is controlled by a quota defined by EU administration. The EC starch quota of Finland is 54 750 tonnes for the marketing years 1998/99-2000/01.

Commercialisation of **biodegradable polymers** is closely connected with the general development of the infrastructure and the related legislation and the political and other decisions made both at the national and the EU level. The same is true for the future market possibilities for **vegetable oil based products** such as lubricants and hydraulic oils.

The legislation of **pharmaceutical and health products** varies considerably already between Nordic countries, and is completely inconsistent in the different European countries. Therefore, it is difficult (in some cases impossible) to manufacture products which would suit the standards of the whole Europe. Without the possibility for such large scale production competitive capacity of health products is poor (Arno Latvus, personal communication).

2.5 Economic issues

In the beginning of 1995 Finland became a member in the European Union. According to a study by Sipiläinen et al. (1998), the membership brought severe challenges for the agricultural sector in Finland, because agriculture had been previously sheltered almost totally from foreign competition. The situation was worsened by the fact that due to the northern location agricultural production costs in Finland are much higher than in most areas of Europe. To soften the impact a transitional period until the year 2000 will be applied.

The study of the development of farm incomes before and after the EU-accession showed that during the transition period the agricultural income and the profitability will decrease drastically in all production lines (both plant and animal production) and in all regions.

One of the targets included in the proposal Agenda 2000 is to maintain a competitive income level in the Finnish agricultural sector. In order to solve the problem of high production costs different types of direct supports have been applied. The results of the study (Sipiläinen et al., 1998) implicate that in the case of the Finnish farm sector, direct supports are likely to cause many unwelcome side effects. If the proposal Agenda 2000 is realised as such, in some cases even the difference between sales revenue and variable production cost is negative. This development would severely diminish the motivation of farm entrepreneurs, because agricultural income would not any more depend directly on the economic result of the production, but on administrative support payments. Consequently, the proposal Agenda 2000 would worsen the current problems caused by weak economic incentives for enterpreneurship. Within the support areas it is punishing the most effective farms while rewarding the ineffective ones. Outside the best production areas it will **increase the number of farms for which extensive farming based** emphasise the adjustment reactions which were induced by the EU-accession. It would increase the political risk of farming, because the economic results of the farms would depend to a larger extent on supports, the level of which is determined in a political process.

Non of the present industrial crops in Finland is profitable to the grower without subsidies. Therefore, the EU subsidy policy is largely going to define which crops are grown, and whether non-food production is competitive with food or feed production.

2.6 Other items

The Central Union of Agricultural Producers and Forest Owners (MTK) prefers to support production of crops which can benefit from the growing conditions in Finland. Such crops would not compete directly with the agricultural products from more favourable growth conditions found in most of the other EU countries. New industrial crop species are welcome, provided processing of the products is organised in a realistic way. MTK may also in some cases obstruct the production of crops which it does not believe to have realistic market potential. Furthermore, MTK is not ready to finance new facilities for processing industrial crops, but considers this to be the expertise area and responsibility of some other parties (Ilpo Mattila, personal communication).

3. PRIORITISATION

Climate is the most decisive factor for the nature of field crop production in Finland. The country is about 1 100 km long (situated between the latitudes 60°N and 70°N), and the climatic conditions vary considerably. In southern Finland, the growing season is 170 days, but in the north only 100 days. There is considerable variation in the effective temperature sum as well: in the south it is 1 300 and in the north 500 day degrees. From time to time there is frost even in the middle of the summer in all parts of the country.

The short growing season brings about considerably lower yield levels of crop species than in Central Europe. Cultivation of wheat and oil-seed plants is restricted to southern Finland while barley, oats, grasses and potatoes can be cultivated in most parts of the country (Hömmö and Hemming, 1996; Skjelvåg, 1998). Furthermore, the unit size of agricultural businesses are small, and therefore it is difficult to maintain profitable operation. In 1996 the average area of arable land in the productive farms was 22.9 ha, 72% of farms had less than 20 ha arable land (Yearbook of Farm Statistics, 1997). Because of the high production costs and low producer prices, the EU subsidy policy will largely determine which crops are profitable in the future.

It has been estimated that about 0.8 to 1 million hectares of arable land will be set aside from the food production before the end of this century. If most of this land is abandoned, the consequences for employment and attention has been focused on such non-food areas where amounts of production and cultivation area can be high (Ministry of Agriculture and Forestry, 1995).

Starch is already the most important industrial crop product, and the paper industry will continue using it. It is possible to achieve sufficient yield levels with many starch crops in Finland. The northern growth conditions are especially favourable for barley, which in Finland contains unusually high amounts of starch. The potato starch quota and EU subsidy policy are the most important factors determining the amounts of production.
The strengths of the Finnish starch industry are highly developed processing methodology and good quality raw materials. Finland is one of the leading countries considering the technological know-how about the use of starch products in the paper industry. A considerable amount of research is going on, and there are good facilities for performing this research (Virolainen, 1997; Kari Nurmi, Raisio Chemicals, personal communication).

Production of crops which could replace short **fibre** wood cellulose represent an interesting new group of plants. If the processing can be organised, the cultivation of such crops could take up a large part of the available surplus land in the future. The plant most potential with this purpose is reed canary grass, which has been studied quite intensively in Finland during recent years.

In addition to the possibility of utilising surplus fields in the future, the other main direction in the development of non-food production is manufacturing speciality products with a high degree of working-up. In the production of herbs for **natural health products, pharmaceuticals**, and for other **green chemical products**, Finland has the advantage of a non-polluted environment, the amounts of heavy metals being considerably lower than in many other European countries. Weather conditions inhibit the growth of many pests and disease organisms, which is a benefit for the organic production of herbs. In addition, an intense and short growing season in Finland favours internal quality such as taste and aroma of herbs. The knowledge of cultivation and processing methods is clearly at an expert level in the areas that the Finnish producers have specialised in. However, natural health products form a very large and diverse product group, which is still developing and a lot of research is still needed. The lack of co-ordination between numerous different small projects seems to be a particular problem in this area. Furthermore, the market demand of such products is limited even in central Europe, and therefore the cultivation area required for production of specialist plants in the future is probably going to be well below that for carbohydrate and fibre crops.

Small to medium scale production of industrial products from **oil crops** already exists in Finland. According to Kari Nurmi, Raisio Chemicals (personal communication) the amounts of industrial crop plants available as well as the domestic markets of non-food products are generally too small for large scale industry to specialise in the likely to continue having both food and non-food products in their product range.

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4.1 Cropping and stocking patterns for agriculture and horticulture
4.1.i Total yields of the most important crops (million kg), 1970-1997

	1970	1975	1980	1985	1990	1995	1996	1997
Winter wheat	146.4	129.5	89.1	48.6	137.4	52.5	108.4	83.7
Spring wheat	262.9	492.0	267.6	423.5	489.5	327.0	350.9	380.4
Rye	131.4	80.7	123.6	71.8	244.2	57.7	86.9	47.3
Barley	933.4	1241.9	1533.6	1853.8	1720.2	1763.5	1859.6	2003.5
Oats	1329.7	1450.1	1258.3	1217.8	1661.8	1097.2	1260.8	1243.4
Mixed grain[1)]	64.7	47.4	33.7	26.5	43.5	35.1	41.8	48.5
Turnip rape and rape	n/a	22.2	87.6	89.3	117.0	127.9	89.4	92.9
Peas	2.6	10.5	11.1	13.6	9.1	10.9	13.3	13.1
Potatoes	1135.9	679.6	736.2	707.7	881.4	798.0	765.7	754.1
Sugar beet	430.6	640.4	850.5	739.4	1125.0	1110.0	896.6	1354.9
Hay	3120.2	2170.7	1830.7	1654.1	1206.5	1086.1	1047.3	862.5
Silage	928.3	2025.4	4180.8	4552.5	4318.1	5633.2	5551.0	5630.0

Source:Statistical Yearbook of Finland 1997 and Yearbooks of Farm Statistics
1) including cereal mixes and legumes + cereal

4.2 Current industrial crops (1997)

	Cultivation area, ha	Yield, tonnes/ha	Domestic production, tonnes	Exports, tonnes	Imports, tonnes	Used in non-food production, tonnes
Wheat (winter & spring)	124 000	3.62	464 100	124 903	194 155	93 110
Barley	533 400	3.44	2 003 500	308 255	21 572	271 170
Potatoes	40 900	22.71	754 100	4 308	29 968	261590
Sugar beet	31 700	38.82	1 354 900	0	0	n/a
Turnip rape and rape	55 300	1.52	92 900	1	49 479	270
Linseed	2207	0.683 [1)]	1507.4 [2)]	0 [3)]	247.3 [3)]	n/a
Flax	994	4.4 [4)]	4373.6 [5)]	1.9 [6)]	138.1 [6)]	4373.6
Hemp	74	n/a	n/a	3.9 [7)]	13.1 [7)]	n/a
Herbal seeds and medicinal plants	1894	n/a	n/a	n/a	n/a	n/a

Sources: Balance Sheet for Food Commodities, 1997 (preliminary), Official Statistics of Finland, Foreign Trade Statistics (Board of Customs)

1) oil production / ha, an average of the tests of the leading cultivar 'Helmi' (Salo and Sankari, 1998)
2) estimated by multiplying the average ha production with the number of hectares under linseed cultivation
3) Import and export of raw linseed oil
4) average production estimated from 1996 figures, pulled non-seeded material
5) estimated by multiplying the average ha production with the number of hectares under flax cultivation
6) raw and processed flax fibres together
7) raw and processed hemp fibres together

4.3 List of industrial crop products
(Trends in production are not available)

Oil crops

Linseed:
- wood protective oils
- anti rust-oils
- pharmaceuticals

Rape and turnip rape:
- plant oil based de-inking compound for recycling paper
- lubricants
- hydraulic oils
- bio-fixer for plant protection chemicals

Fibre crops

Reed canary grass:
- pulp - paper industry (short fibre)

Fibre flax:
- textiles

Linseed:
- reinforced composites (under development)
- insulation materials (under development)
- growth substances (under development)

Fibre hemp:
- reinforced composites (under development)
- thermal insulation materials (under development)

Carbohydrate crops

Barley:
- starch - paper industry
- biodegradable polymers (under development): thermoplastic starch, paper/board coating, infection moulding, film & sheets, fibres

Potato:
- wet end starches
- spray starches
- cationic starches
- coating starches
- biodegradable polymers (under development)

Wheat:
- starch - paper industry
- biodegradable polymers, poly(lactic acid) (under development): fibres and non-woven webs, blown films, thermoformed strong objects, extrusion coating for paper and board

Crops with speciality uses

Sugar beet: - betaine: additives in animal feed, pharmaceuticals, cosmetics, fermentation industry, plant protection
Herbs: - natural health products, pharmaceuticals, essential oils, cosmetics, plant protection, preservatives, fragrances, aroma compounds, dyes
Cataranthus - vinblastine - pharmaceutical (under development)
Tansy: - plant protection, essential oils, wood protection
Caraway: - natural health products, pharmaceuticals, essential oils, additives in animal feed, plant protection, wood protection, preservatives, cosmetics

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KEY AREAS: linen textiles

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KEY AREAS: printed bread bags, film, sheets, sacks and pallet hoods

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KEY AREAS: biodegradable polymers, drug delivery

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KEY AREAS: On-line coating on the paper machine

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4.4.iv Other interest groups

4.4.v People and organisations contacted

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4.5 Gross margin calculations, based on 1997 values (not available for all industrial crops, (1 FIM = 0.167 ECU, 28.9.-98)**)**

A calculation example of the production costs of reed canary grass, 1996
(calculation made for energy production, but cultivation and harvesting methods can be same, when producing reed canary grass for making pulp)

Energy grass	Reed canary grass		Round baling, spring harvest	
Interest, %		**5**	**Yield, ton/ha**	**6.0**
Salary, FIM/h		**50**	**Nr of harvests, year**	**9**
Nitrogen input, kg N/ha		**65**	**Bale density, kg/m3**	**140**

				Per harvest year				
Energy grass	**Quantity**	**a´FIM**	**FIM/ha**	**FIM/ha**	**FIM/ton**	**%**	**h/ha**	**h/ton**
Crop establishment	once/rotation							
Seed, kg	15	53	795.0	88.3	14.7	3.5		
Fertilizers, kg	375	1.25	468.8	52.1	8.7	2.1		
Pestisides, l	2.0	31.30	62.6	7.0	1.2	0.3		
Machine work, h	3.93		539.8	60.0	10.0	2.4	0.44	0.07
Man work, h	4.60	50	230.2	25.6	4.3	1.0	0.51	0.09
Crop establishment, total			**2096**	**233**	**39**	**9.3**		
Crop management	9 times/rotation							
Fertilizers, kg	325	1.25	406.3	406.3	67.7	16.2		
Machine work, h	0.29		34.1	34.1	5.7	1.4	0.26	0.04
Man work, h	0.34	50	17.2	17.2	2.9	0.7	0.31	0.05
Crop management, total			**458**	**458**	**76**	**18.3**		
Harvest	9 times/rotation							
Bale string, m	1143	0.06	69.7	69.7	11.6	2.8		
Plastic for storage, t	6.0	8.0	48.0	48.0	8.0	1.9		
Machine work, h	1.82		329.0	329.0	54.8	13.1	1.82	0.30
Man work, h	2.42	50	121.1	121.1	20.2	4.8	2.42	0.40
Harvest, total			**568**	**568**	**95**	**22.7**		
Drying	0.0	0.0	0.0	0.0	0.0	0.0		
Transport (30 km), ton	6.0	45.7	274.3	274.3	45.7	11.0		
Land rent			800.0	888.9	148.1	35.5		
Oportunuty cost for woring capital				82.9	13.8	3.3		
Total cost				**2504**	**417**	**100.0**		
Machine work, total				423	71	16.9	2.51	0.42
Man work, total				164	27	6.5	3.24	0.54

		Per harvest year		
Variable machinery cost	FIM/ha	FIM/ha	FIM/t	%
Crop establishment	119.9	13.3	2.2	0.5
Crop management	7.9	7.9	1.3	0.3
Harvest	66.4	66.4	11.1	2.7
Variable machinery cost	194	88	15	3.5
Variable drying cost	0	0	0	0.0

		Per harvest year		
Fixed machinery cost	FIM/ha	FIM/ha	FIM/t	%
Crop establishment	419.9	46.7	7.8	1.9
Crop management	26.2	26.2	4.4	1.0
Harvest	262.5	262.5	43.8	10.5
Fixed machinery cost	709	335	56	13.4
Fixed drying cost	0	0	0	0.0

source: TTS-Work Efficiency Institute, 1998

A calculation example of the production costs of barley, 1997

	Unit	Price	Model 1 Amount	FIM	Model 2 Amount	FIM
Returns (A-area)						
Grain[1)]	kg	0.72	3000	2160	4000	2880
CAP-ha subsidy[2)]	ha	1114	1	1114	1	1114
National subsidy[3)]	ha	235	1	235	1	235
Environmental subs.[4)]	ha	1053	1	1053	1	1053
LFA-subsidy[5)]	ha	970	0	0	0	0
Total returns in the A-subsidy area				**4562**		**5282**
Total returns in the B-subsidy area				**4839**		**5559**
Total returns in the C1-subsidy area				**4642**		**5362**
Total returns in the C2-subsidy area[6)]				**4531**		**5251**
Total variable costs[7)]				**1481**		**1918**
Contribution margin A (A-area)				**081**		**3364**
Contribution margin A without area based subsidies (A-area)				**679**		**962**
Costs of labour	h	55.00	11	605	12	660
Contribution margin B (A-area)				**2476**		**2704**
Contribution margin B without area based subsidies (A-area)				**74**		**302**
Machines, buildings and General costs						
Total costs of machinery				1420		1498
Total costs of buildings				447		466
General costs				350		350
Machines, buildings and General costs, Total				**2217**		**2314**
Contribution margin C (A-area)				**259**		**2390**
Costs of arable land (interest and drainage)				**820**		**920**
Net profit / loss (A-area)				**-561**		**-530**

1) At present the price of barley for industrial purposes is the same as fodder barley
2) CAP subsidy for a reduced price is in the A-area approximately 1114 FIM/ha (calculated for a yield level of 3.4 tons/ha), B- and C1-area 917 FIM/ha (yield 2.8 t/ha), and other areas 753 FIM/ha (yield 2.3 t/ha).
3) The national subsidy for the transition period is 125 FIM, and national subsidy for fodder grain is in A-area 110 FIM/ha, B-C2-area 70 FIM/ha.
4) The environmental subsidy is in A-area 1053 FIM/ha, B-area 597 FIM/ha, C1 area 400 FIM/ha and C2-area 253 FIM/ha.
5) LFA (Less Favourable Areas) subsidy is 0 FIM /ha in A-area, and in the B- and C-areas 970 FIM/ha.
6) In the C2-area the subsidy for northern areas is 200 FIM/ha.
7) Including costs of: own and purchased seed for sowing, fertiliser, liming, herbicide treatment, tractor work, harvesting, drying, freight and commissions and working capital (30%).

Source: Enroth A. (1997) Mallilaskelmia maataloudesta 1997. *Maaseutukeskusten liiton julkaisuja* nro 922

A calculation example of the production costs of spring turnip rape, 1997

	Unit	Price	Model 1 Amount	FIM	Model 2 Amount	FIM
Returns (A-area)						
Main product[1)]	kg	0.72	1750	2713	2000	3100
CAP-ha subsidy[2)]	ha	1567	1	1567	1	1567
National subsidy[3)]	ha	235	1	235	1	235
Environmental subs.[4)]	ha	1053	1	1053	1	1053
Total returns in the A-subsidy area				**5568**		**5955**
Total returns in the B-subsidy area[5)]				**6042**		**6429**
Total returns in the C1-subsidy area				**5845**		**6232**
Total returns in the C2-subsidy area[6)]				**5898**		**6285**
Total variable costs (in A-area)[7)]				**1635**		**1897**
Contribution margin A (A-area)				**3933**		**4058**
Contribution margin A without area based subsidies (A-area)				**1078**		**1203**
Costs of labour	h	55.00	12	660	13	715
Contribution margin B (A-area)				**3273**		**3343**
Contribution margin B without area based subsidies (A-area)				**418**		**308**

1) The price of spring turnip rape 1.55 FIM/kg. The price was determined by world market prices during September - October 1998.
2) CAP subsidy for a reduced price for farms which have set a side land (according to the general system) is in the 1567 FIM/ha.
3) The national subsidy for the transition period is 125 FIM, and national subsidy is in A-area 110 FIM/ha, and B-C2-area 70 FIM/ha.
4) The environmental subsidy is in A-area 1053 FIM/ha, B-area 597 FIM/ha, C1 area 400 FIM/ha and C2-area 253 FIM/ha.
5) LFA (Less Favourable Areas) subsidy is 0 FIM /ha in A-area, and in the B- and C-areas 970 FIM/ha.
6) In the C2-area the subsidy for northern areas is 200 FIM/ha.
7) Including costs of: own and purchased seed for sowing, fertiliser, liming, herbicide treatment, tractor work, harvesting, drying, freight and commissions and working capital (30%).

Source: Enroth A. (1997) Mallilaskelmia maataloudesta 1997. *Maaseutukeskusten liiton julkaisuja* nro 922

A calculation example of the production costs of sugar beet, 1997

	Unit	Price	Model 1 Amount	FIM	Model 2 Amount	FIM
Returns (A-area)						
Beet[1]	kg	0.314	32500	10205	40000	12560
Additional price[2]	ha	0.032	32500	1040	40000	1280
National subsidy[3]	ha	270	1	270	1	270
Environmental subs.[4]	ha	1727	1	1727	1	1727
LFA-subsidy[5]	ha	970	0	0	0	0
Total returns in the A-subsidy area				**13242**		**15837**
Total returns in the B-subsidy area				**13335**		**15930**
Total returns in the C1-subsidy area				**13850**		**16445**
Total variable costs (A-area)[7]				**5798**		**5917**
Contribution margin A (A-area)				**7444**		**9920**
Contribution margin A without area based subsidies (A-area)				**5447**		**7923**
Costs of labour	h	55.00	27	1485	29	1595
Contribution margin B (A-area)				**5959**		**8325**
Contribution margin B without area based subsidies (A-area)				**3962**		**6328**

1) 0.314 FIM/kg is an average price in the A quota
2) The additional price for sugar beet was 0.32 FIM/kg in 1997
3) The national subsidy for sugar beet production is 270 FIM/ha in A- and B-areas. In C1-C2P areas the amount is 785 FIM/ha, and the general subsidy for northern areas is 200 FIM/ha
4) The environmental subsidy for sugar beet growers is in A-area 1727 FIM/ha, and in other areas 859 FIM/ha.
5) LFA (Less Favourable Areas) subsidy is 0 FIM /ha in A-area, and in the B- and C-areas 970 FIM/ha.
7) Including costs of: seed & sowing, fertiliser, liming, herbicide treatment, pesticide treatment, tractor work, thinning, harvesting, freight and working capital (30%).

Source: Enroth A. (1997) Mallilaskelmia maataloudesta 1997. *Maaseutukeskusten liiton julkaisuja* nro 922

A calculation example of the production costs of spring wheat, 1997

	Unit	Price	Model 1 Amount	FIM	Model 2 Amount	FIM
Returns (A-area)						
Bread grain[1)]	kg	1.05	3400	2160	4250	4463
Fodder grain	kg	0.72	600	432	750	540
CAP-ha subsidy[2)]	ha	1114	1	1114	1	1114
National subsidy[3)]	ha	358	1	358	1	358
Environmental subs.[4)]	ha	1053	1	1053	1	1053
Total returns in the A-subsidy area				**6554**		**7555**
Total returns in the B-subsidy area				**5841**		**6842**
Total returns in the C1-subsidy area				**5644**		**6645**
Total variable costs[5)]				**2473**		**2934**
Contribution margin A (A-area)				**4081**		**4620**
Contribution margin A without area based subsidies (A-area)				**1529**		**2068**
Costs of labour	h	55.00	12	660	13	715
Contribution margin B (A-area)				**3421**		**3905**
Contribution margin B without area based subsidies (A-area)				**869**		**1353**
Machines, buildings and General costs						
Total costs of machinery				1498		1576
Total costs of buildings				452		468
General costs				350		350
Machines, buildings and General costs, Total				**2300**		**2394**
Contribution margin C (A-area)				**1121**		**1511**
Costs of arable land (interest and drainage)				**920**		**1020**
Net profit / loss (A-area)				**201**		**491**

1) The average price of wheat was 86.98 FIM/kg + addit. price 0.18 FIM/kg = 1.0498 FIM/kg in November, 1997

2) CAP subsidy for a reduced price is in the A-area approximately 1114 FIM/ha (calculated for a yield level of 3.4 tons/ha), B- and C1-area 917 FIM/ha (yield 2.8 t/ha), and other areas 753 FIM/ha (yield 2.3 t/ha).

3) The national subsidy for the transition period is 125 FIM, and national subsidy for wheat is in A-area 260 FIM/ha, B-area 200 FIM/ha, and the subsidy for northern areas in C1-C2 areas is 200 FIM/ha.

4) The environmental subsidy is in A-area 1053 FIM/ha, B-area 597 FIM/ha, C1 area 400 FIM/ha and C2-area 253 FIM/ha.

5) Including costs of: own and purchased seed for sowing, fertiliser, liming, herbicide treatment, tractor work, harvesting, drying, freight and commissions and working capital (30%).

Source: Enroth A. (1997) Mallilaskelmia maataloudesta 1997. *Maaseutukeskusten liiton julkaisuja* nro 922

4.6. Figures and regulations of the use and composition of sewage sludge in agriculture in Finland

Production and agricultural use of sludge.

	Dry matter (tonnes/year)		
	1995	1996	1997
Sludge produced by the waste water treatment plants	141 000	130 000	136 000
Sludge used in agriculture	47 000	49 000	53 000

Source: Collected by the Finnish Environment Institute from the register of water and sewerage systems

Sludge used in agriculture.
Average content (mg/kg dry matter)

Parameters	1995	1996	1997
METALS			
Cadmium	1.3	0.7	1.04
Copper	283	291	290
Nickel	41	48	34
Lead	47	43	39
Zinc	575	636	606
Mercury	1.6	1.4	1.3

Chromium	82	91	84

ELEMENTS

Nitrogen (total N)	28 000	31 600	32 000
Phosphorus (total P)	20 000	26 000	28 000

Source: Collected by the Finnish Environment Institute from the register of water and sewerage systems

Upper limits of heavy metal content of sludge and sludge mixtures which are used in agriculture, mg/kg dry matter. (Council of State, Decision N:o 282/94)

Cadmium	3.0	Nickel	100
Chromium	300	Lead	150
Copper	600	Zinc	1500
Mercury	2.0		

Upper limits of heavy metal content of agricultural land where sludge or sludge mixture is used, mg/kg dry matter. (Council of State, Decision N:o 282/94)

Cadmium	0.5	Nickel	60
Chromium	200	Lead	60
Copper	100	Zinc	150
Mercury	0.2		