IENICA

Interactive European Network for Industrial Crops and their Applications

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EXECUTIVE SUMMARY

This report aims to provide a general overview of the situation of renewable raw materials in Switzerland. The focus lays on technical usage. Energetic aspects are not part of the report. The report is divided into four chapters with identical structure: oil, fibres, carbohydrates and crops with special uses.

The Swiss government supported renewable raw materials in agriculture financially over the past decade. Acreages of renewable raw materials, however, remain very small. The report presents research results of recent years, some market assessments, legal and economic issues and an estimation of the most important barriers to progress for renewable raw materials for technical uses in Switzerland.

Because renewable raw materials have been substituted in the past decades by products based on mineral oil, processing industry is optimised for mineral oil. For this reason, efforts are required to re-substitute mineral oil by renewable raw materials, such as fibres or vegetable oils. Until now, the Swiss processing industry rarely processes plant fibres or vegetable oils. Local crop cultivation is negligible and imported quantities are small. Facilities for the extraction of fibres or starch do not exist in Switzerland. This missing link between agriculture and processing industry can be a main reason for the small importance of renewable raw materials such as fibres or carbohydrates in Switzerland. Furthermore, Swiss agronomic production costs are especially high and raw material such as vegetable oils can be imported more cheaply from abroad. Only the sector of medicinal plants seems to be successful and acreages of locally grown medicinal plants are expected to increase in the next years, especially for organic farming. One reason for this up-coming agronomic sector could be the well-organised value chain, starting with structured associations of farmers up to public research and processing companies. This efficient value chain doesn't exist for fibre, oil or carbohydrate crops in Switzerland.

Until now, there is no umbrella organisation or official contact office in Switzerland that organises and optimises the value chain for renewable raw materials from farmers up to the resulting product. Such a function could be very helpful to overcome barriers to progress for renewable raw materials, especially against the background of decreasing mineral oil reserves. Renewable raw materials will be the only possible substitute for mineral oil in some years. Furthermore, the Kyoto-protocol signed in 1997 obligates Switzerland to reduce emissions such as CO_2. The substitution of mineral oil-based products with plant-based materials would be a sustainable possibility. The presented report intends to give the status quo of activities and opportunities for renewable raw materials in Switzerland in the year 2003 and provides information to support future decision for policy.

General Situation

The Swiss Government decided to support actively the growing of crops for the production of renewable raw materials in agriculture in the year 1993. The aims of this support program can be divided in three categories:

- agricultural policy: reasonable use of abandoned arable farmland
- ecology: use of biological degradable products and reduction of CO_2-emission (Kyoto-protocol)
- energy: promotion of renewable energy

Areas that were provided for the cultivation of renewable raw materials had to be arable farmland. The cultivation of renewable raw materials on grassland was not allowed. The cultivation area for renewable raw materials was limited to 2000 ha. The financial support by government was 3000 Fr./ha (2000€/ha) per year, except grass and field wood which could get only 1500 Fr/ha (1000€/ha) per year. The payment of this contribution required a contract with a purchaser.

In 1998, the newly released law about contributions for agriculture (Ackerbaubeitragsverordnung) replaced these conditions. Contributions were paid for all fibre plants and some oil plants such as oilseed rape, sunflower or hemp. Contracts with purchasers were not required. Furthermore, financial support for pilot plants for processing of renewable raw materials were approved. Research on the agronomic aspects for the cultivation of crops that could be used as renewable raw materials was initiated. After some newly started activities on renewable raw materials, activities nearly stopped both on the agronomic and the market side. Only a few companies are still processing renewable raw materials; public research is negligible. There are no legislative targets or loan programs to support the application of products based on renewable raw materials like in Germany.

In Switzerland, there is no state-run office engaged in renewable raw materials. For this reason, activities on renewable raw materials are carried out quite independently in the agronomic and industrial sector. This report should provide relevant information of all these activities of about the last ten years.

METHODOLOGY

The report was developed at Agroscope FAL Reckenholz, the Swiss Federal Research Station for Agroecolgy and Agriculture. Since agronomic research on renewable raw materials occurred at FAL and other stations, information about agronomic research should be quite complete. Information about processing industry was found mainly using the internet. For this reason, the list of companies can not be exhaustive. Market assessment could not be developed within the given time, for this reason only already published market assessments for Switzerland or Germany are presented. Barriers to progress and priorities were developed after discussions with different persons. Due to the missing state-run office that could provide needed information for this report, this report does not claim for absolute completeness. For some sectors, data is not available in the needed forms and quantities, for example for crops with special uses. Differentiation between medicinal or cosmetic plants and herbs for alimentation is often not possible. Nevertheless, the report gives a useful overview of activities on renewable raw materials in Switzerland and can revitalise discussion on this topic.

Thanks

We thank all persons who provided us information or discussed with us about renewable raw materials. We especially thank Mister C. Rey (Agroscope RAC Changins, the Swiss Federal Agricultural Research Station) for his helpful support for the chapter on crops with special uses.

Abbreviations

ETH: ....Swiss Federal Institute for Technology

FAL: ....Agroscope FAL Reckenholz, Swiss Federal Research Station for Agroecology and Agriculture

FAT: ....Agroscope FAT Tänikon, Swiss Federal Research Station for Agricultural Economics and Engineering

RAC:..Agroscope RAC Changins, Swiss Federal Agricultural Research Station

A Oil Crops

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1 Opportunities

1.1 Science and technology

This chapter outlines the relevant agronomic and technical research on oil crops and its oil over the last years in Switzerland. In the following sectors, only public research is mentioned due to the fact that technical research is often carried out by private companies and not published. Since there is only little technical public research on vegetable oils in Switzerland, some foreign work is also presented.

1.1.1 Agronomic research

Agroscope FAL Reckenholz, the Swiss Federal Research Station for Agroecology and Agriculture (FAL) and Agroscope RAC Changins, the Swiss Federal Agricultural Research Station (RAC) verify each year approved and new varieties of **oilseed rape** (*Brassica napus*), **sunflower** (*Helianthus annus*) and **soya** (*Glycine max*). The best varieties are recommended to the farmers in form of lists of recommended varieties (Hebeisen and Charles 2003, Hebeisen and Pellet 2002, 2003). Additional to yields, contents of oleic, linoleic and linolenic acid are published for the different oilseed rape varieties. Within the variety trials, also high oleic types of sunflower are tested and recommended varieties are known. These high oleic types contain more than 80% of oleic acid. High oleic oilseed rape varieties are available, but unsuitable in terms of yield and other substances. Breeding is going on for these species. New released varieties will be included in the variety trials. The cultivation of all these oil crops is well known and cultivation guidelines are published (LBL 2003).

Linseed (*Linum usitatissimum*) is not included in the annual variety trials of oil crops. Nevertheless, the RAC carried out variety trials with linseed during the years 1994–1996. On average, seed yield varied between 1.7 and 2.3 t/ha with an oil content of 32%. In a three year trial of the FAL, yields were about 1.6 t/ha on average (Mediavilla 1999). The main fatty acid of linseed oil is linoleic acid. Newly released varieties in Germany show higher yield potential, but these varieties are not yet tested under Swiss conditions. Between 1996 and 1998 an agricultural cooperative society (Landi Zürich Oberland) carried out trials with linseed on a few hectares. The trials took place on farm in collaboration with local farmers. The cultivation of the crop ran without problems. Some difficulties occurred during harvesting due to entangling straw in the harvesting machine. Since the price of the produced oil was significantly higher than the imported linseed oil and a market for the linseed-straw was non-existent, the trials were stopped (Nussbaumer 1996). Conclusions of these trials resulted in a data sheet for the cultivation of linseed in Switzerland (Buri and Mediavilla 1996).

Little research was carried out with **Caper spurge** *(Euphorbia lathyris)* between the years 1987 to 1990 at the RAC (Reust and Dutoit 1992). Only one variety, provided by the Federal Agricultural Research Center at Braunschweig in Germany, was cultivated. Yields laid on 1.5. to 1.8 t/ha, whereas the oil content was on about 51% with over 80% of oleic acid. But it has to be considered that at this time, the agronomic characteristics of the variety were insufficient especially due to an uneven maturation.

Crambe (*Crambe abyssinica*) and **Gold of pleasure** (*Camelina sativa*) were also the object of field research (Mediavilla 1997). Crambe was well adapted to the Swiss climate and could be harvested at the end of July. Yields laid between 0.8 and 2.7 t/ha, higher yields are expected if the cropping system can be optimised. Crambe offers an oil content of about 30-45% with a content of erucic acid up to 60% (Schuster 1992). Yields of different varieties of Gold of pleasure varied in a two year trial in Switzerland on one site between 0.5 and 2.1 t/ha. Oil content is high and up to 42% is possible. The oil is characterised by more than one third of linolenic acid. Other main components are eicosen acid and linolen acid.

Beside those investigated oil crops, many other species could provide interesting oils. Most of them are not yet tested in Switzerland, mainly because breeding is not advancing, and no varieties with promising agronomic characteristics are available. A complete overview of the potential of oil crops, their characteristics and the state of breeding and literature can be found in Schuster (1992).

1.1.2 Research for technical use

Crude vegetable oils have to be processed for most of the technical uses. These processes are often a corporate secret and depend strongly on the desired end product. Perhaps due to this fact, no public research was found on this topic in Switzerland. At the end of the following chapter, some German studies are shortly presented.

In the early nineties, a practical experiment was carried out to get experience with lubricant and hydraulic oil based on oilseed rape (Stadler and Schiess 1996, Stadler 1996). The examined lubricant oils that were commercially available were recommended for practical use, for example as loss lubrication for chainsaw or for pumps in agricultural applications. But it was also shown that mineral oil should only be substituted with biological degradable lubricant based on oilseed rape if the manufacturer authorises this lubricant. A test with agricultural machines showed that due to the higher oxidation potential of vegetable oil based lubricants compared with mineral oil, the viscosity and the intervals of oil change decreased slowly. Another test was carried out to prove corrosion protection based on rapeseed oil. Several products that were available on the market have been examined. Metal surfaces without discoloration were sufficiently protected, whereas a grubby and pasty film was observed on coloured surfaces.

An Environmental Assessment Tool for Organic Synthesis (EATOS) was developed at the Swiss Federal Institute for Technology (ETH) Zürich in close collaboration with the University of Oldenburg. The developed computer program allows the assessment of the environmental index of chemical reactions. The environmental index is composed of an environmental factor (quantity of waste) and an environmentally specific load factor. The computer program can be downloaded on http://www.chemie.uni-oldenburg.de/oc/metzger/eatos/deutsch.htm.

No public research was carried out in Switzerland about the specific oil components and their possible uses and applications. In Germany, an immense literature search was carried out within the SOFA-Project (Seed Oil and Fatty Acid Project). The resulting database is published on http://www.bagkf.de/sofa/. For the application of high oleic oils, information can be found in the report of Naracon (2001) or on http://www.high-oleic.de. A seminar about biological degradable lubricants and procedure material was held in Germany in 1999. The presentations of research projects applications were published as proceedings (FNR 1999).

Another application area for vegetable oils will be the use of high-oleic oils especially for loss lubricants, hydraulic or motor oils, metal machining or compressor oils. A market study for the EU marketplace estimated that more than 10% of the market volume could be substituted with high-oleic vegetable oils (Naracon 2001). Due to the current availability of varieties, sunflowers are particularly favoured. But also oilseed rape or safflower are potential high-oleic oil crops.

Another German study explored the possibilities of renewable raw materials in the varnish industry (Schütte 2000). Vegetable oils could be used for the production of varnish, although they are not often utilised actually. The study gives a good overview of the possible application and the concerning description in the literature.

1.2 Industry

Since there is no official contact office in Switzerland for companies that are working with vegetable oils or that are interested in starting to process vegetable oils, it is quite difficult to find these companies. Through a search on the internet and through personal contacts some Swiss companies processing vegetable oils could be identified. The following list of companies working with vegetable oils is not complete, but can give an overview of the status of vegetable oils used for industrial purposes in Switzerland.

The Swiss family firm **Bucher AG Motorex** (http://www.motorex.ch) produces chain and motor oil based on rapeseed oil. In recent years, the enterprise processed Swiss rapeseed oil for the production of the technical oils. In the year 1995, oilseed rape for lubricants was produced on a surface of 240 ha in Switzerland (Regenass 1995). Due to the high prices of Swiss oil and the resulting high prices of the final product, the company buys rapeseed oil on the world market.

The company **Omya AG** (http://www.omya.ch) produces binders for synthetic resin. For the production, oil of linseeds, cocos and soya are processed. Oils are bought on the world market. Until 1994, the company pressed oil of linseed and oilseed rape on an own press. Due to problems to sell the rape meal and a decreasing demand of the Swiss Federation on rapeseed oil as a provision for the event of war, the self pressing of oil was stopped.

Auro Naturfarben (http://www.auro.de) is a small company producing wall paints for the Swiss market in licence for AURO-Germany. All paints are based on linseed and rhizinus oil. The company would be very interested to process Swiss linseed oil. Most of the imported linseed is produced after certified organic farming guidelines in Germany in the surrounding area of the facilities of AURO-Germany.

It was not possible to present all the processors of technical vegetable oils in Switzerland. Some information about the quantity of processed vegetable oils are given by the official import statistic. The Swiss Agency for Customs Administration records all goods crossing the Swiss border. Seeds and vegetable oils for technical purposes are recorded as separate category. The imported quantities of the year 2002 are listed in Table 1. Since all the indigenous produced oil is used for human nutrition or energetic purposes, this statistic provides valuable information about the whole consumption of vegetable oils by the industry. Export of vegetable oils and seeds for technical purposes are negligible. In the following list, only oil crops that could be cultivated in Switzerland are listed.

Table 1. Imported quantities of seeds and oils for technical purposes to Switzerland in the year 2002 (tonnes). Other oils for technical purposes like soya or palm oil are not separately registered.

	Total	Germany	France	EU without Germany/ France	Other countries
Linseeds	**16**	16			
Rapeseeds low EA[1] for oil [2]	**5,212**		5,212		
Rapeseeds low EA[1]	**103**	100	3		
Rapeseeds others	**1**			1	
Sunflower seeds others	**5**	1	1	3	
Rapeseed oil low EA[1] refined	**142**	128	13	1	
Rapeseed oil low EA[1], crude	**1,057**	1,031	20	6	
Rapeseed oil low EA[1], refined barrelled	**1,144**	1,086	32	26	
Mustard seeds	**162**	93	5	18	46
Linseed oil crude	**60**	42		17	1
Linseed oil refined barrelled	**947**	943		4	
Linseed oil refined others	**31**	27	3	1	

Source: Swiss Agency for Customs Administration, 2003
[1] EA: erucic acid
[2] mainly for energetic purposes (methyl ester)

Some oil seeds are pressed in Switzerland, other oils are directly imported. Table 1 shows clearly that rapeseed oil is the most used oil in the Swiss industry. In the year 2002, about 7,000 tonnes were processed, but about two-thirds were used for the production of oilseed rape methyl ester as a substitute for diesel. Linseeds are also often used in industry. In the year 2002, about 1,000 tonnes were processed for different end products.

Beside these oil seeds that are imported to Switzerland, there are other interesting oil crops that could be used for technical uses. Already in 1992, a Swiss working group carried out the potential of different oil crops in Switzerland for the next years (Gantner *et al.* 1992). A good overview of the potential of oil crops, their main fatty acids and their agronomic suitability for Switzerland can be found there. Table 2 shows a summary of the report. Oil crops differ widely in their spectrum of fatty acids and a lot of different oil crops with special fatty acid spectrum are known. Some of them are already cultivated, others could be cultivated and for a third part, some further agronomic research is needed. Barriers to progress the cultivation of these different oil crops are discussed in chapter 2.

Table 2 Characteristics of potentially or already cultivated oilseed crops in Switzerland

Fatty acids		Maximum content of main fatty acid [%]	Average of oil content [%]	Relative yield to oilseed rape [%]	Suitability of cultivation for CH	Varieties tested in CH
Petroselin acid (C18:1)						
Coriander	*Coriandrum sativum*	82	22	80	medium	no
Fennel	*Foeniculum vulgare*	71	14	20	good	no
Oleic acid (C 18:1)						
Sunflower [1)]	*Helianthus annus*	83	48	80	medium-bad	yes
Safflower [1)]	*Carthamus tinctorius*	80	35	60	bad	no
Caper spurge	*Euphorbia lathyris*	84	48	50	medium-bad	no
Oilseed rape [1)]	*Brassica napa*	60	42	100	very good	yes
Linoleic acid (C18:2)						
Sunflower	*Helianthus annus*	80	48	90	medium-bad	yes
Safflower	*Carthamus tinctorius*	79	35	60	medium-bad	yes [2)]
Oil poppy	*Papaver somniferum*	78	46	60	good	yes [2)]
Soya	*Glycine max.*	52	18	70	good	yes
Linolenic acid (C18:3)						
Linseed	*Linum usitatissimum*	67	39	60	good	no
Gold of pleasure	*Camelina sativa*	44	39	75	good	no
Erucic acid (C22:1)						
Oilseed rape	*Brassica napa*	54	42	90	very good	yes
Crambe	*Crambe abyssinica*	59	35	70	medium	no
Brown Mustard	*Brassica juncea*	53	40	60	medium	no

Source: Gantner *et al.*, 1992
[1)] High oleic types
[2)] Variety trials within a privately sponsored research program for the use of consumption use, carried out at FAL.

1.3 Markets

In Switzerland, only four species of oil crops are actually suitable for a local cultivation. These crops are oilseed rape, linseed, sunflower and soya. Sunflower and especially soya are only recommended for the warmer and drier regions of Switzerland. The main characteristics of the crops can be found in the following Table 3.

Table 3 Actually cultivated oil crops in Switzerland and their main characteristics.

	Grain yield [t/ha]	Oil content [%]	Oil yield [t/ha]	Oleic acid 18:1 [%] [2)]	Linoleic acid 18:2 [%] [2)]	α-Linoleic acid 18:3 [%] [2)]
Oilseed rape	4	42	1.7	13-38	10-22	1-13
Sunflower	3	45	1.4	14-43	40-44	-
Linseed	3	32	1	15-30	10-30	40-68
Soya [1)]	3.5	20	0.7	23-32	48-52	2-12

1) beside the oil fraction, the crop contains a high content of protein
2) according to Schuster (1992)

In Switzerland, the cultivated areas of oil crops for technical purposes are small. The following table (Table 4) shows the acreages between the years 1993 and 2001.

Table 4 Acreages of oil crops for technical and energetic purposes in Switzerland between 1993 and 2002 (hectares). About 1300 ha on average and most of the sunflower seeds are designated for the production of methyl ester as diesel substitute.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Oilseed rape [ha]	-	49	1,345	1,410	1,513	1,477	1,576	1,231	1,115	1,063
Sunflower [ha]	3	6	2	43	1	1	20	25	38	42
Linseed [ha]	-	-	36	12	9	18	-	-	-	2

Source: Swiss Federal Statistical Office, 2003

As can be seen in the table above, only three oil crops were cultivated in the last years. Oilseed rape for lubricants was manufactured by one enterprise, but due to lower prices of oilseed rape on the world market, cultivation in Switzerland was stopped in 2002 (see also chapter 1.2). Linseed was cultivated within the scope of cultivation trials but stopped due to the non-existence of a market (see also chapter 1.2 and chapter 2). Sunflower is only cultivated for energetic purposes.

Since there are no official market studies available, the estimation of the market potential for oil products based on vegetable oils is quite challenging. Vegetable oils of different species provide a wide range of fatty acids and depending on the aimed product, the adequate oil has to be chosen.

For technical uses, only oilseed rape and linseed are imported. If the imported quantities were provided by Swiss production, the following cultivation areas would be necessary (Table 5).

Table 5 Estimated surfaces for oil crops to provide the imported quantities of seeds and oil for technical uses of the year 2002 and yields of seeds and oil of oil crops in Switzerland on average.

	Imported seeds [t]	Imported oil [t]	Grain yield [t/ha]	Oil content [%]	Oil yield [t/ha]	Estimated surface [ha]
Linseed	16	1038	3	32	1	1038
Oilseed rape	104	2342	4	42	1.7	1378

The highest quantities of imported oil crop for technical uses come from oilseed rape. The main part of this oilseed rape is processed to biological degradable lubricants.

Gantner *et al.* (1992) gave some prospects about the potential of oil crops in Switzerland. The main potential was seen for oilseed rape as lubricants, hydraulic oils or formwork oils. The potential sales on a 5 to 10 year scale was estimated to 6,000 tonnes, corresponding to a cultivated area of 3,500 hectares. The importance of financial support by the government was demonstrated.

Detailed market studies for the segment of lubricants or hydraulic oils are missing in Switzerland. In Germany, a few studies have been carried out: the proportion of biologically degradable lubricants was about 3.5% of the whole lubricant market (Kaup 2002). For the year 2002, the proportion was estimated to increase to 10-15% of the whole market (Mang 1998, Luther 1999). Biologically degradable lubricants are especially successful in three market sectors:

- Static industrial gearing and hydraulic oils
- loss and cooling lubrication
- mobile hydraulic oils

Biodegradable lubricants received respectable market share in these segments in Germany, especially for the use in environmentally sensitive areas. Lubricants based on vegetable oils suffer from higher costs compared with mineral oil, due to higher costs of basic raw materials and lower purchase quantities (Kaup 2002).

One application for biologically degradable lubricants is its use in environmentally sensitive areas, such as for forestry or for shipping traffic. In Switzerland, the use of these products is recommended but not regulated by law (see also 2.5).

There is a wide range of other oil crops for the technical use. At the moment, there seems to be no defined demand for such other oil crops for technical uses in Switzerland.

1.4 Environmental

A study was carried out in Switzerland to determine the environmental aspects of the production of oilseed rape for lubricants (Wolfensberger and Dinkel 1997). Environmental impacts were estimated by using life cycle analysis, by estimating soil fertility and possible changes in flora and fauna. The study did not find relevant positive or negative effects on the environment by producing lubricants based on rapeseed oil, compared with extensively used grassland. However, the environmental benefit of using vegetable oil based substances in environmentally sensitive areas, such as forests, instead of mineral based oils was especially highlighted.

An overview of some potential environmental impacts of rape, sunflower, linseed and soya is given in Table 6.

Table 6 Survey of some environmental impacts of oilseeds.

	Autumn-sown oilseed rape [1)]	Sunflower [1)]	Linseed [2)]	Soya[1)]
Nitrogen demand [kg/ha]	140	60	40-50	-
Phosphate demand [kg/ha]	80	60	50	70
Potassium demand [kg/ha]	140	400	100	145
Magnesium demand [kg/ha]	20	55	-	25
Herbicide use [4)]			()	
Pesticide use [4)]			-	-
Fungicide use [4)]			-	-
Erosion potential [3)]	low	high	n.s.	high
Water requirement [4)]	medium	high during flowering period, low during maturation	low	high during flowering period

: rare to frequent application; : frequent to regular application; (): no substances approved; n.s.: not specified

[1)] according to LBL (2003)

[2)] according to Ammon *et al.* (1996)

[3)] according to Vullioud and Maillard (1998)

[4)] own estimation

2 Barriers to progress

2.1 Scientific

Besides the actually cultivated oil crops, a number of other oil crops could be grown in Switzerland. For some of them, cultivation already takes place in other countries, for others, cultivation and the availability of varieties is not given. An overview of all the possible oil crops is given on http://www.ienica.net/cropsdatabase.htm or in Schuster (1992).

If new oil crops should be put forward in Switzerland, further agricultural research is needed. Linseed for example could be an interesting crop for technical oils. But actually, no research is going on and newly released varieties are not yet tested in Switzerland.

Research should also provide cultivation guidelines for new and potential oil crops. These guidelines have to include recommended varieties, best dates for sowing and harvesting, plant protection, harvesting methods and if necessary, further processing of the seeds. The development of guidelines takes at least two or three years.

For some oil crops, no varieties with promising agronomic characteristics are available. In this case, breeding has to take place. Species with the need of breeding are often disappointing in terms of even maturation, yield and oil or fatty acid content.

2.2 Technical issues

The development and production of a new product ties up resources and contains risk. These uncertainties are only taken by an enterprise if a big market potential of the new product is expected. Due to these circumstances, an official contact person and financial contributions by the government could be helpful to strengthen efforts for new products based on vegetable oils. In Germany, a state-aided support program for the launch of biogenous fuel and lubricants was initiated. The demand for financial support was extremely high and the program will go on (http://www.pflanzenoelinitiative.de).
Research on vegetable oils for technical uses is very small in Switzerland. No public research on potential use of vegetable oils or assessments of market potential have been carried out. In Germany, a lot of research and estimations of potential markets has been realised. Most of the results are available on the internet, for example on http://www.fnr.de. For example, a market study was carried out to estimate the possible applications for high oleic vegetable oils, such as

sunflower, oilseed rape, soya or safflower (Naracon 2001). Oleic acid is traditionally extracted from suet. High oleic varieties from different oil crops contain more than 80% oleic acid. In Switzerland, some varieties are tested within the variety trials, but they are not yet commercially grown on a large scale. As a result, no free market exists and no market price is established.

2.3 Environmental

Oilseed rape is the most important oil crop in Switzerland. The crop is well adapted to the Swiss climate. Soya and sunflower are only recommended in regions with a warmer and drier climate in Switzerland due to the climatic requirements of these crops. Linseed is actually not cultivated in Switzerland, but there seems to be no relevant environmental barriers for this culture. An overview of the environmental demand of the mentioned oil crops is given in Table 7.

Table 7 Survey of environmental requirements to oil crops in Switzerland.

	Autumn-sown oilseed rape [2)]	Sunflower [2)]	Linseed [1)]	Soya [2)]
max. m.a.s.l.	800	500	1200	500
Vegetation period [days]	300	130-150	100-120	140-150
Soil preferred	medium-heavy	medium (-heavy)	light-medium	medium
Cultivation break [years]	3	5	6-7	3
pH soil	6–7.5	6–7.5	5.5-6.5	6.5–7.5
Performance on dry soil	medium-(good)	bad	good	bad

m.a.s.l.: meters above sea level
[1)] according to Ammon et *al.* (1996)
[2)] according to Vullioud and Maillard (1998)

2.4 Legislative issues

There are no restrictions to the cultivation of oil crops in Switzerland. All potential oil crops can be grown legally, even if they are potential drug plants, for example poppy or hemp. To eliminate problems with police, farmers growing these plants are advised to be able to prove satisfactorily for which purposes the plants are grown.

Since oilseed rape, sunflower and soya are grown on large areas in Switzerland, plant protection products are registered for these crops. For linseed and all other potential oil crops, no plant protection products are registered yet.

The use of biological degradable materials such as hydraulic oils or loss lubricants in environmental sensitive areas like forests or groundwater reserves are only recommended. A prohibition by law for the use of mineral oil based products in such areas could enforce the use of vegetable oil based lubricants or hydraulic oils.

2.5 Economic issues

Until 2003, only oilseed rape, soya, sunflower, hemp and oil pumpkin could profit from a crop linked financial contribution of 1,500 CHF/ha (1,015 €) per year (ABBV, Art. 1, Ziff. 1). Additionally, a general contribution of 1,600 CHF/ha (1,080 €) per year is paid as a direct payment related to surface, independent of the crop. No contribution was paid for the cultivation of linseed or other oil crops due to the non-existing surfaces of this cultivation. For the year 2004, a revision of the law is envisaged and linseed should be accepted in the list of supported oil crops. The reason for this change is the interest of cow farmers that like to grow linseed for the nutrition of cows to supply them with ω-3-fatty acid.

The Swiss government gives financial support to crops for pilot or demonstration purposes. These crops have to serve for the technical proving of new systems or for the acquisition of new scientific or technical data. Another aim of the crops can be the economic estimation of a potential bringing onto the market of the produced product (ABBV, Art. 10, Ziff. 2). The minimum of the financial contribution is 20 CHF (13 €) for 100 kg oilseeds (ABBV, Art. 12a, Ziff. 3 b).

3 Priorities

The cultivation of oilseed rape, sunflower and soya is well established in Switzerland. Until now, linseed has not been cultivated in Switzerland, one reason could be the missing financial contribution by the government. Other oil crops like oilseed rape, sunflower and soya can get this financial support of the government. The contribution is substantial, even if prices of Swiss oil cannot compete against world market prices. Since 2004, also linseed can profit of this financial support. Linseed seems to be an interesting and adapted oil crop, some tonnes of linseeds are imported for technical uses each year. In Switzerland, there are actually no oil crops cultivated for technical uses. But linseed and oilseed rape are imported from abroad, corresponding to an acreage of about 1,000 ha each.

Beside the mentioned oil crops, several other oil crops could be grown in Switzerland, such as caper spurge or crambe. Since there is no defined demand for technical use of these vegetable oils, agronomic research is not needed imperatively.
Harvesting and storage of oilseeds is technically known and does not cause problems. There are two big oil plants in Switzerland. Both of them do not extract oil chemically, but press oil by mechanical pressure.

Only a few companies process vegetable oils for technical purposes in Switzerland. A main reason is that vegetable oils are more expensive than mineral oil. Furthermore, processing techniques have to be developed to treat vegetable oils. These restrictions can cause barriers to advance research and development of products based on vegetable oils.

To encourage Swiss enterprises with low research and development budgets to invest in new products or processing methods, the Innovation Promotion Agency (KTI) supports research programs initiated by small and medium-sized enterprises. The agency bears the personal costs of researchers. Contributions from industry cover project-related expenditure: setting up facilities, licences and any equipment used for research purposes (http://www.bbt.admin.ch/kti/profil/d/index.htm). These research programs could be an interesting way to promote the development of vegetable oil based products.

In Switzerland, no information centre with consolidated knowledge about oil crops and their potential use for technical applications exists. Companies with interest in processing vegetable oils have to look for all information about the characteristics, quality, availability and prices of the wanted raw material themselves. This missing links between agriculture and industry could be a possible reason for the poor use of vegetable oils in Switzerland.

On the consumer side, financial incentives could stimulate demand of vegetable oil based products. In Germany for example, a state-aided support program for the launch of biogenous fuel and lubricants was initiated. The demand for financial support was extremely high and the program will go on (http://www.pflanzenoelinitiative.de).

As conclusion, vegetable oils for technical uses are rarely processed in Switzerland. If this product group should be promoted, efforts have to be made both on the industrial and the market sector. On the agronomic side, oil crops can be grown easily since cropping techniques are well known.

B Fibre Crops

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1 Opportunities

1.1 Science and technology

Several fibre crops can be cultivated under Swiss conditions. A number of scientific work has been carried out to assess the potential of fibre crops for their agronomic suitability and opportunities for technical uses and success on the market. The focus points lay on hemp, miscanthus and a few years ago also on kenaf. Research on flax was small. The following two sections outline the public research, carried out in the field of agronomy and technical use of plant fibres.

1.1.1 Agronomic research

Within a transnational project of the northern regions of Switzerland and southern Germany (Baden-Württemberg), field research was carried out to clarify questions of varieties, seed densities or fertilisation of fibre crops (Meister *et al.* 1999). The project concentrated on hemp, miscanthus and kenaf. These crops were estimated to be suitable to the Swiss climate.

The work resulted in several publications relating to agronomic questions of **hemp** (*Cannabis sativa*) growing (Mediavilla *et al.* 1998a, 1999a, 1999b). A large overview of the situation of hemp cultivation in Switzerland was published (Bassetti and Mediavilla 1998), and a decimal code for growth stages of hemp was elaborated (Mediavilla *et al.* 1998a, 1999c). In field trials in Switzerland in the year 1997, maximum stem yield reached up to 14.8 t of dry matter per hectare (Mediavilla *et al.* 2001). Bark yield showed a development similar to that of the stem yield and reached 5.8 t of dry matter per hectare. Fibre yield was highly correlated with stem and bark development and reached up to 4.1 t of dry matter per hectare. Furthermore, the content of Tetrahydrocannabinol (THC) in industrial hemp varieties was examined (Mediavilla and Brenneisen 1996) and a list of recommended hemp varieties for industrial purposes was published (Mediavilla 1999a).

Agronomic research was also carried out on **miscanthus** (*Miscanthus x giganteus*) to answer questions of cultivation techniques and fertilisation. Trials of the year 1993 to 1996 assessed the potential yield of miscanthus in Switzerland on 15 to 20 t of dry matter per hectare. For practice, lower yield between 10 and 15 t of dry matter per hectare was conceded due to considerable amount of residual stubbles remaining on the field. A leaflet with recommendations for the cultivation of miscanthus was published (Mediavilla *et al.* 1994).

To find herbicides tolerated by miscanthus, field trials were carried out with several substances. Some of these substances have been registered for miscanthus (Serafin and Ammon 1995a).

Agronomic research also took place for **kenaf** (*Hibiscus cannabinus*). Field trials pointed out that the tested varieties are inadequately adapted to the wet and cool climate of Switzerland (Mediavilla *et al.* 1997). Problems with weeds, diseases and humidity at harvest occurred. Yields of stalk dry matter were about 5 to 12 t/ha, resulting in a fibre yield between 1 and 1.5 t/ha. Additionally, herbicide trials were carried out and suitable active substances were found and registered (Serafin and Ammon 1995b). A leaflet for farmers with the most important agronomic characteristics of kenaf was published (Ott *et al.* 1995).

Agroscope FAL Reckenholz, the Swiss Federal Research Station for Agroecology and Agriculture (FAL) carried out field trials to assess the potential of **flax** (*Linum usitatissimum*) in Switzerland (Mediavilla 1999b). In a three-years variety trial, the best variety Ariane yielded about 9 t of dry matter per hectare on average, resulting in a yield of bast fibres of about 2.2 t/ha.

All this research pointed out that hemp, miscanthus and also flax are potential field crops for fibre production in Switzerland. For promoting the cultivation of fibre crops, a leaflet was published for farmers. In a short form, all the relevant agronomic aspects for the successful cultivation of flax, kenaf, miscanthus and hemp were summarised (Ammon *et al.* 1996).

1.1.2 Research for technical use

Plant fibres can be used in a wide range of applications. A short overview of possible technical uses is given in Keller (1997). In Switzerland, some activities were carried out on processing methods for fibres of hemp and miscanthus. Due to the very low agronomic potential of kenaf, no supplementary public work was done with these fibres.

Some research dealt with the question of the optimal harvest time of hemp for a good fibre quality. The work of Mediavilla *et al.* (2001) showed that the best harvest time for a maximum yield of stem, bark and fibres is reached at male flowering ("technical maturity"). However, studies of Keller (2001a) pointed out that optimal harvest time for a mechanical decortication of non-retted, dried hemp stems is approximately 3-4 weeks later at the beginning of seed maturity.

Hemp could be an interesting fibre for textile production. Until now, no environmentally friendly process is available to detach hemp fibres from the fibre bundles. This separation is indispensable for the use of the hemp fibres in a industrial scale for example for a cotton spinning process. At the Institute for Manufacturing Automation of the Swiss Federal Institute of Technology (ETH) at Zurich, a research project over several years is carried out to find a method to extract hemp fibres in a quality admitting an application for the cotton spinning process (Leupin 1998). Various methods to extract hemp fibres are developed and tested. Furthermore, different industrial hemp varieties are tested to find the optimal harvesting time and the most suitable variety for the intended use. The project is ongoing and first results will be published.

Hemp or grass fibres could be used as an ecological insulation material for buildings. A project promoted by the Swiss Federal Office of Energy was initiated to examine the possibilities and marketability of blow-in insulation made of fibre hemp or grass fibres, compared with insulation made of recovered paper (Hersener and Keller 2002). The project was also initiated by three producers of insulation materials. One company produces a cellulose based insulation, using recovered paper. This product "Isofloc" is available on the market and is market leader on this business segment. "Isofloc" acted as a standard, the following new materials were compared with this standard regarding the physical characteristics, the application and the marketability:

- 2B Gratec, new product of the company 2 Bio AG, insulation made of grass fibres
- Insulation made of pure hemp, produced on a small scale for the project by the company Läderach Agro
- Isofloc (company Isofloc), already available on the market
- Mixture of hemp and Isofloc
- Mixture of 2 B Gratec and Isofloc

The tests showed that grass fibres are competitive to paper fibres. The insulation made of hemp had no technical advantages over the Isofloc standard. Furthermore, an insulation of hemp is more expensive than an insulation made of recovered paper or grass. Grass fibres are a by-product of the production of bioethanol and proteins using grass (http://www.2Bio.ch).

In 1992, first seedlings of miscanthus were imported to Switzerland. The co-operative society biomass technology Genossenschaft Biomasse Technologie (GSB) was incorporated in 1997 to organise cultivation, marketing activities and the development of products based on miscanthus fibres. Internal differences led to the liquidation of the society.

The syndicate Interessengemeinschaft Miscanthus (IGM) develops new products based on miscanthus (http://www.miscanthus.ch). This research is financially supported by the Swiss government within the program RegioPlus. One project is the formulation of a fibre-reinforced concrete. A number of patents are filed. Another application of miscanthus fibres are biodegradable plastics that can be formed from a liquid compound. The third use of miscanthus fibres is the production of a granulate material that can be pressed for example into biodegradable cards that are usually based on synthetic materials (Kohler 2001). If at least one of these products was launched and produced on a larger scale, the areas of cultivation of miscanthus in Switzerland could increase noticeably. In the year 2002, prices for miscanthus lay between 160 and 200 CHF/t (105 and 130€/ha). If demand for miscanthus based products increase, prices for producers of miscanthus are also expected to increase (Grandjean 2003).

An extensive research work was carried out by Keller (2001a) at Agroscope FAT Tänikon, the Swiss Federal Research Station for Agricultural Economics and Engineering (FAT). The project lighted up the whole process of a biodegradable polymers reinforced by plant fibres. Included were the extraction of the hemp fibres with a degumming process using biological processes or steam explosion, the compounding of the natural fibres with a biodegradable matrix and its biodegradable characteristics. The results of the study were published in different journals or reports (Keller at al. 1997, 2001, Keller 2001b).

At the ETH at Lausanne, a group was working on novel pulp fibre reinforced thermoplastic composites. The work was carried out with fibres of miscanthus (Lundquist *et al.* 2003). Futhermore, a life cycle assessment of biofibres replacing glass fibres as reinforcement in plastics was carried out (Corrbière-Nicollier *et al.* 2001).

Furthermore, the enzymatic degumming of bast fibres of **ramie** (*Boehmeria nivea*) was investigated. The results indicate that the pectinolytic activity of the bacterium *Amycolata sp.* plays an active role in degumming of ramie bast fibers (Leupin 1996, Brühlmann *et al.* 2000).

A division of Rieter AG fabricates under-floor shields for cars among other products. The company tested flax as reinforcement some years ago, but the product quality was not convincing. Further tests with other fibres were made, and with the utilisation of a new production process, the company will start the production of fibre-reinforced under-floor shields.
The Swiss Federal Laboratories for Materials Testing and Research (EMPA) aims at the development of an international competence centre for renewable raw materials. Together with their co-operation partner IBF Innovative Bio Fibre Corporation AG (see chapter 1.2), they develop and study methods to reach constant, product specific fibre qualities focused on jute, kenaf or hemp as the main source (http://www.empa.ch).

In Germany, an extensive research work was executed to test different local fibre crops for the production of fibre-inforced duroplasts (Müssig 2001). The work laid the main focus on the optimal coordination of the whole value chain, ranging from the cultivation of flax or hemp to the technical application.
Also in Germany, a database for polymers reinforced by plant fibres is available on the internet (http://www.n-fibrebase.net). The database provides information about plant fibres for design engineers and purchasers.

1.2 Industry

Even tough renewable raw materials are encouraged by the Swiss government, only a small number of enterprises work with natural fibres. In the following section, some of these companies are presented. There are also other companies working with fibres such as sisal or cocos. These companies are not listed, due to the missing contacts to these companies.

The Swiss company **NAPAC** (http://www.napac.ch) described a new method to turn fibres of miscanthus into granules that can be used to produce all types of cast parts. Napac products can be used alternatively to a large number of plastic products. Until now, mainly plant pots are produced, but several other shapes and applications are discussed. Napac products are 100% biodegradable and are returned to the natural cycle after use. A big market is identifiable especially for plant pots because of the reduction of the work step of digging out plant pots after use. An enlargement of the production and an expansion to other countries seems realistic. At the moment, miscanthus is cultivated in southern Germany and Switzerland. The company won the Swiss Technology Award of the year 2003.

The start up company **2 B Bioreffinery AG** (http://www.2bio.ch) developed an new innovative technology for the fractionation and profitable conversion of a range of non-woody biomass raw materials such as grass, brewers spent grain and others. The resulting end products are energy (biogas or ethanol), fibres and protein. The company built up a demonstration and pilot plant in 1996 with a vital support given by the Swiss Agency for the Environment, Forests and Landscape (SAEFL). A separate fibre business unit was formed in 2000 to strengthen the marketing of the fibre products.

Bioenergie Schaffhausen AG was the first company using this new technology and started operations in October 2001. Various qualities of grass based on extensive pastures and silage from a total area of approximately 700 ha are processed. The plant is able to process about 5,000 t of dry matter per year, resulting in a fibre production of about 2,000–2,500 t per year. The fibres are already used as loose blow-in insulation material with the trade name "2 B Gratec" (see also chapter 1.1.2). Proteins can be extracted of the grass fibres and are used for animal feeding. The first production under maximum output was planned for the year 2003 (Widmer and Müller 2002). But in summer 2003, the company ran into financial problems. The reason was seen in the undervalued invested capital (7 Mio CHF, 4.6 Mio € resp.) and the inadequately performance (Schweizer Bauer 2003).

The **Innovative Bio Fiber AG (IBF)** (http://www.tebo.ch/ibf/deutsch/home.htm) is specialised in the production and conditioning of plant fibres for technical applications. Their core competence is the production of raw material, refining of raw material and supplying customers defined qualities. IBF produces its plant starting material from quickly growing fibre crops such as kenaf, jute, sisal, hemp and ramie. The company works with partners in Europe, Asia, Africa and South America. Customers of the products are seen in the car-, the building-material, the furniture- and the plastic industries.

Some plant fibres are also used as intermixture for soil used in house and garden. These plant fibres substitute peat.

In the year 1993, the new start-up company **Terbatec** was started. The company intended to bring the "Terbatec-fibre-technology" to the market. A new processing machine was developed for the mechanical conversion of mainly kenaf. Fibre based products were seen in the segments of biodegradable mulch film, packing material or building materials (Terbatec 1993). To ensure a minimal quantity of fibre for processing, cultivation contracts for 200 ha of kenaf were announced. Different publication in agronomic newspapers and journals brought the new crop to mind and animated farmers to cultivate kenaf (Suter 1993). Expected yields were 5 to 7 t of dry material per hectare, the paid minimum price was about 250 CHF/t dry material (165 € /t). It was intended to sell the produced kenaf paper as of 1996. Distribution should be organised in collaboration with Dow Europa SA. (Zürcher 1995). In the first year of production in 1993, about 200 farmers were sought to cultivate kenaf. The paper, used for wrapping or as mulch cover sheet, should be produced in the paper mill Bischofszell. This company went out of business at the end of 1997 (trade register, http://www.zefix.ch). The company Terbatec was defunct due to liquidity problems in mid-June 1997 (trade register, http://www.zefix.ch).

It was not possible to find all companies working with natural plant fibres in Switzerland. A idea of the quantities of processed fibres can be obtained by regarding the import statistic. The imported amounts of flax and hemp are listed in Table 1.

Table 1 Imported quantities of fibres of flax and hemp to Switzerland in the year 2002.

	Total [t]	Germany [t]	France [t]	Belgium[t]	Netherlands [t]	Austria [t]	Europe [t]	Asia [t]
Flax								
crude or retted	42	<1	42					
crushed or swing led	<1			<1				
non-spun	38	4	<1	34			<1	<1
waste	166	5	161					
tissue > 85% flax crude or bleached	71	15	2	11	<1	13	28	2
tissue > 85% flax coloured	64	14	5	5	<1	5	33	2
tissue < 85% flax crude or bleached	17	1	<1	1		13	2	
tissue < 85% flax coloured	30	6	1	<1	<1	2	19	<1
Hemp								
crude or retted	21	1			12	8		
treated non-spun incl. waste	231	200	17		14		<1	
yearn	5	1				3	1	

Source: Swiss Agency for Customs Administration, 2003

The table shows that the total amount of non-spun plant fibres is about 200 tonnes per year for flax and hemp each. In Switzerland, plant fibres of hemp or flax can not be extracted due to missing processing machinery. For this reason, all fibres are imported. Flax is mainly bought in France, hemp mainly in Germany. In 2002, no hemp **tissue** was imported; contrary to flax where additional to the non-spun fibres nearly 200 tonnes of **tissue** was also imported.

1.3 Markets

Although cultivation of plant fibres such as flax or hemp has a long tradition in Switzerland, the current production is small as can be seen in Table 2. The biggest areas of industrial fibre crops are covered with miscanthus. The fibres are used for several products and projects (see chapter 1.1.2 and chapter 1.2). About 170 farmers grow miscanthus on about 193 ha (year 2002). About 100 farms are members of the IGM, about 50 farms of the western part of Switzerland are expected to join the IGM. The remaining 20 farms use their miscanthus fibres for other purposes (Grandjean 2003).

The areas of flax collapsed due to the non-existence of a fibre market. The areas of hemp are negligible, the reason can be found in the non-existence of a decortisation possibility in Switzerland. The cultivated area of kenaf declined to zero after some years of cultivation. Problems of weed, diseases, humidity at harvest and the missing market were responsible for the failure of this species. The reason for the non-existence of a market for hemp or flax can be found in chapter 3.

Table 2 Cultivated areas of fibre crops in Switzerland since 1993 (start of the statistical registration for fibre crops).

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Miscanthus [ha]	88	167	213	275	280	290	267	267	255	249
Hemp (mostly production of grain or essential oil) [ha]	-	10	7	4	1	32	34	31	31	35
Kenaf [ha]	90	35	64	45	4	49	-	-	-	-
Flax (inclusive linseed) [ha]	-	-	36	12	9	18	-	-	-	2

Source: Swiss Federal Statistical Office, 2002

A market estimation for flax fibres was carried out by Gantner *et al.* (1992). The work was initiated by the Swiss government. For all the potential sectors of industrial or technical uses a demand of more than 10,000 t milled fibres was estimated. This assessment refers only to flax fibres since there was a misunderstanding on hemp. The report based on the presumption that no hemp cultivation is allowed in Switzerland not even for fibre production. As conclusion, a potential cultivation area of some thousand hectares for flax was seen in 1992 if some qualifications are fulfilled, such as new harvesting and processing techniques. The flax production has been seen as a niche production relying on subsidies.

In 1999, another study was carried out at the FAL to analyse the market and market potential for products based on fibres of miscanthus, flax, hemp and kenaf in Switzerland (Sell and Mediavilla 1999). The estimated tonnage of plant fibres that could be used in Switzerland are listed in Table 3. A number of experts was interviewed on topics of economy, ecology, market, product quality, techniques and policy within the scope of fibres processing. Most of these experts believed that hemp and flax had only a small chance to enter into the textile market even if the fibres are cottonnised because they can not be processed on rotor spin machinery. The market potential of long fibres of hemp or flax was also assessed to be small due to the high raw material and processing costs beside the missing of infrastructure.

Fibres of different plant species are used in the building industry. For this industry, an umbrella association is missing. This factor hampers the estimation of the used fibre based products an the assessment of the potential market potential. For the sector of insulation material, the study (Sell and Mediavilla 1999) assessed a market share of 5-10% within the insulation market. The potential quantity of alternative insulation could amount to 3,500 to 9,000 t. This quantity corresponds to a cultivated area of 500 to 1,000 ha of hemp. At the moment, the used alternative insulations are all imported due to the non-existence of a processing crop for short fibres in Switzerland (see also chapter 2.2). The main reason for the small market share is seen in the higher prices of alternative insulation material. A German study, carried out in 1999, concluded in the same way (Murphy *et al.* 1999).

Table 3 Market potential of fibre products in different industrial sectors.

Sector	Product line	Crop	Market potential short term (3 years) [t]	Market potential long term [t]
Paper production	Technical filter paper	Hemp	None	5000
Paper trade	Special paper	Hemp	15 - 20	Not specifiable (dependent on trend)
Weaving mill	Different textiles	Flax, hemp	Flax: 100, hemp: 15	No increase
Insulant	Blow-in insulation, insulation mat	Hemp, flax	Hemp:Blow-in insulation: 375, insulation mat: > 10	500 -1000
Fibre concret	Reinforcement	Flax, hemp	Not specifiable	Not specifiable
Building board	Particle board	Hemp, flax, miscanthus	Not specifiable	Not specifiable
	Building element	Hemp hurds	400 (≈80 ha)	increase
Loam building	Clay brick, plaster	Hemp, flax, miscanthus	10 - 20	Strong increase
Garden	Substitution of peat, mulch, litter	Hemp, miscanthus	Hemp: 20, miscanthus: 800	Strong increase
Geo textiles	Planting vegetation	Flax, hemp	Not specifiable	100 - 150
Fibre reinforced plastics	Pot, packing, automotive industry	Hemp, flax	1000 - 1500	increase

Source: Sell and Mediavilla, 1999

A comparison of the imported amounts of plant fibres and the estimated market potential shows that imported amounts underachieve the estimated potential of fibres.

In Germany, a study about the price- and market estimation of plant fibres was carried out in 2000 (Karus *et al.* 2000). The study provides a lot of data about market and market estimation for hemp and flax fibres. New processing plants for the production of flax fibres will be installed in Germany in the next years. About 90% of the production should be used for the production of insulation materials, about 8,400 t of flax fibres should be sold in 2005. The most important countries producing flax in Europe are France, Belgium and the Netherlands with a total production area of about 50,000 ha. Nearly the whole amount of long fibres and about 50% of short fibres of flax are produced in these countries. A new flax industry is built up in Germany, Great Britain, Finland, Sweden and Denmark. Objectives of this industry are technical markets.

Hemp is produced on only about one quarter of the flax areas of the European Union. France is the most important hemp producer with acreages of about 10,000 ha (year 2000). More than three quarters of these hemp fibres are processed in the cellulose market; other technical applications are increasing. The biggest increase for hemp is seen in the market of composites. The companies that were investigated in the study intend to increase hemp production from 28,000 t per year in 1999 to 47,000 t in 2005. Prices for technical plant fibres need to be between 0.5 and 0.7 € per kg to be competitive.

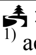
1.4 Environmental

Hemp, miscanthus and flax are crops that can be grown with a very low level of fertiliser and plant protection products. The cultivation of these crops could contribute to an extensive and environmentally-friendly agriculture. Especially flax and miscanthus are very suitable to organic farming due to their low requirements of fertiliser. For flax, weed control has to be done seriously. Hemp profits from a good weed-competition and few diseases. Miscanthus is a perennial culture and well adapted to the Swiss climate. The potential cultivation areas of kenaf are very small in Switzerland due to the high heat requirement.

For all fibre plants, no severe damages caused by insects or pathogens have been reported. For that reason, no chemical treatments against diseases or pests are admitted. For flax, no herbicides are approved until now. The registration of some herbicides is expected for 2005 due to an increasing market for linseed for nutritional purposes. In Table 4, an overview of some environmental impacts of fibre crops suitable to Switzerland is given.

Table 4 Survey of some environmental impacts of fibre crops.

	Hemp	Flax	Miscanthus	Kenaf
Nitrogen demand [1)]	80 - 120	30 - 50	30 - 50	75 - 90
Phosphat demand [1)]	60	50	30 - 50	60
Kali demand [1)]	150	100	50 - 100	120
Mg demand	n.s.	n.s.	n.s.	n.s.
Herbicide use [1)]	-	()	 only first year	
Pesticide use [1)]	-	-	-	-
Fungicide use [1)]	-	-	-	-
Erosion potential [2)]	low	medium	low	low
Water requirement [2)]	medium	medium - high	medium	medium - high

 : rare to frequent application;  : frequent to regular application; (): no substances approved; n.s.: not specified
[1)] according to Ammon *et al.* (1996)
[2)] own estimation

A study investigated the ecological effects of the cultivation of miscanthus for the environment (Loeffler and Nentwig 1997). Arthropod fauna was described as similar to other agronomic areas. The contribution of small and well-distributed miscanthus areas contributed to the linking-up of extensive cultivated land areas. Referring to this facet, miscanthus can supplement the functions of hedges and tree rows.

The study of Lips *et al*. (1999) compared several field crops in terms of biodiversity. It was shown that industrial crops such as fibre hemp, miscanthus, oilseed rape or kenaf do not significantly influence the biodiversity compared with other crops.

2 Barriers to progress

2.1 Scientific

2.1.1 Agronomic research

In Switzerland, no variety trials or other agronomic questions of fibre crops are investigated at the moment. For hemp, a variety list for 1997 exists (Mediavilla 1999a), but is not yet actualised. In the last years, new varieties have been developed in Europe, but non of them were tested in Switzerland. These newly developed varieties are bred especially for good fibre quality, for example the newly released variety "Chameleon", registered in the Netherlands. Cultivation of hemp occurs without problems and no further agronomic research apart from variety questions is top priority.

For flax, no variety list exists in Switzerland. Some variety trials were carried out a few years ago (see part B, chapter 1.1.1), but the variety trials were stopped due to the non-existing market for flax fibres. Breeding is going on for flax, and several new varieties were developed in Europe. In Germany for example, several varieties have been registered since 1999. For flax, some further agronomic research would be preferable, since agronomic research was mainly dealing with linseeds. Cultivation of flax is more challenging than the cultivation of hemp, due to the worse weed suppression of these two crops. For both fibre crops, harvesting techniques are not well known in Switzerland. Since both crops are cultivated on big areas in the near foreign countries, experiences with different harvesting machines could more or less be easily transferred to Swiss conditions.

Miscanthus is well known in Switzerland and cultivation and harvesting occurs without problems. Most of the miscanthus fields should be replaced in the next years due to the age of the plants.

2.1.2 Research for technical use

At the moment, research work with plant fibres in Switzerland is very small (see chapter 1.1.2). It seems that no business company is interested to promote technical research on plant fibres. Since there is no active contact between researchers and industrial companies, it is very difficult to estimate their needs. The Swiss government supports research programs if public research collaborations with private companies (see chapter 3).

2.2 Technical issues

Working up of fibres of hemp or flax on an industrial scale is not possible in Switzerland due to missing equipment. Two different processes to separate plant fibres are possible (Drescher and Hanf 1996):

- Detraction of long fibres for textile production: no process unit is available for the extraction of long fibres of hemp or flax on an industrial scale in compliance with different environment protection law. The work of the group of M. Leupin at ETH in Switzerland could probably show new ways (Leupin 1998).
- The processing of flax or hemp fibres for short fibres is known and different machines operate in Europe. No processing plants exist in Switzerland.

2.3 Environmental

Flax and Hemp are fibre crops that can be grown on larger areas in Switzerland due to their environmental demands. Kenaf is too thermophile for Switzerland and for this reason, the crop is actually not cultivated in Switzerland. Miscanthus is suitable to the midland. An overview of the environmental demand of these fibre crops is given in Table 5.

Table 5 Survey of environmental requirements to fibre crops in Switzerland.

	Hemp	Flax	Miscanthus	Kenaf
max. m.a.s.l. [1)]	900	1200	700	500
Vegetation period [days] [1)]	120	100 - 120	several years	210-240
Soil preferred [1)]	medium- heavy	light	n.s.	medium - heavy
Cultivation break [years] [1)]	2 - 3	6 - 7	n.s.	3
pH soil [1)]	< 7	n.s.	n.s.	n.s.
Performance on dry soil [1)]	medium	medium	medium	medium - bad

m.a.s.l.: meters above sea level; n.s.: not specified
[1)] according to Ammon *et al*. (1996)

2.4 Legislative issues

There are no special legislative issues for fibre production. Also cultivation of hemp is allowed, but only registered fibre hemp varieties can profit from a crop-linked contribution (see chapter 2.5).

For hemp and flax, there are actually no plant protection products allowed. For flax, registrations of some herbicides are expected for the year 2005. For miscanthus, herbicides are registered. Since hemp has a good competition against weeds, herbicides are not important for the successful cultivation of the crop. However, the application of herbicides can be an important factor for the successful cultivation and harvest of flax. With the expected registration of some herbicides, the cultivation of flax will become more attractive from the agronomic point of view.

2.5 Economic issues

The Swiss government supports the cultivation of hemp and flax with the oilseed contribution of 1,500 CHF/ha (1,000 €/ha). Until 2003, flax could profit from the general contribution for fibre plants of 2,000 CHF/ha (1,333 €/ha) per year (ABBV; Art. 1 Ziff. 1a, c). Hemp can only profit from the contribution, if the chosen variety is registered on the Swiss Hemp Variety List (Sortenkatalog-Verordnung, annex 4). Additionally, a general contribution of 1,600 CHF/ha (1,080 €) per year is paid as a direct payment related to surface, independent of the crop.

Fibres of hemp or flax should be available for market prices between 0.5 and 0.7 € per kg (Karus *et al.* 2000). Since there have been no studies in Switzerland to determine the potential costs and outputs of a fibre processing company, it is very difficult to define the minimum price for one kilogram of produced fibres of hemp or flax in Switzerland.

3 Priorities

Research of past years in Switzerland showed a high agronomic potential for fibre crops such as miscanthus, hemp or flax. A lot of agronomic research was carried out on these species, and cultivation is sufficiently known for miscanthus and hemp. Only for flax, research activities were low, some further research for fibre production would be preferable. Kenaf could not fulfill the expectations due to the high thermal requirement of this species.

No decortication industry for bast fibre crops exists in Switzerland. For that reason, no bast fibre such as hemp are flax are cultivated. Only miscanthus is grown for industrial purposes, since these fibres do not have to be extracted. One company produces plant pots based on miscanthus fibres, another syndicate (IGM) aims at the production of miscanthus based material, for example as plastic substitution.

Little experience was made on harvesting techniques for hemp and flax in Switzerland. But since cultivation and harvesting of fibre crops are well established in neighbouring countries, these techniques and machines could be imported.

From industry's point of view, plant fibres have to provide qualities at least equal to artificial fibres. Furthermore, a constant availability of fibres is needed for an optimal efficiency of the processing plants. These needs are a challenge for suppliers.

There is no Swiss association attending to the interests and needs of farmers or industry partners working with bast fibres. Such an association would be very helpful to impart knowledge on agronomic questions, fibre qualities and possible uses of the fibres. Furthermore, harvesting and logistics of fibre crops could also be organised by this association or syndicate, since fields are small-scaled in Switzerland. Contacts between interested partners could be made and also knowledge transfer of the numerous foreign research programs to Switzerland would be guaranteed. Since there is no existing network between persons or companies interested in fibres at the moment, the build-up of a fibre association would be preferable. This association could stimulate discussions on fibres and potential application areas. The need of a Swiss centre for the coordination of cultivation, processing and trading of fibres and their products was already discussed in the market study of Sell and Mediavilla (1999). For miscanthus, such a centre exists already: the syndicate miscanthus (IGM) provides contacts between farmers, research and industry. Since miscanthus is a perennial culture, the formation of such a syndicate is easier and interests of farmers are bigger to really push the possibilities to sell the fibres also over a long period. For annual fibre crops such as hemp or flax, the situation is different. Farmers will choose another crop in the next year, if the fibres cannot be sold easily.

To encourage Swiss enterprises with a low research and development budget to invest in new products or processing methods, the Innovation Promotion Agency (KTI) supports research programs initiated by small and medium-sized enterprises (see chapter A). The Swiss government already supports all fibre crops with a crop-linked contribution.

In Germany, the "Fachagentur nachwachsende Rohstoffe" (FNR) provides information about fibre plants and offers market analysis, feasibility studies, marketing concepts and consulting (http://www.naturfaser-wirtschaft.de). A newly built up network should provide information about plant fibres to all the participants (http://www.afpn.org). Furthermore, especially for the launch of plant fibre based insulation material, a loan programme for the price reduction of these insulations started (Förderprogramm Dämmstoffe aus nachwachsenden Rohstoffen).

In Switzerland, fibre production is not yet an attractive alternative to other crops. Due to the missing extraction facilities and the missing practical knowledge, high motivation to advance cultivation and extraction of fibre plants is needed. Furthermore, the enlargement of the European Union could bring plant fibres at low prices and a good quality from the traditional fibre crops - growing countries such as Poland. These developments have to be watched. Demands of industry for plant fibres could increase in the next years, if research on processing of fibre crops is going on and problems of uneven qualities and logistic problems are solved.

C Carbohydrate crops

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1 Opportunities

1.1 Science and technology

In Switzerland, only little research was carried out to assess the potential of carbohydrate crops for non-food products in the last years.

1.1.1 Agronomic research

Sugar crops

Annual varieties trials on **sugar beet** (*Beta vulgaris*) occur. The best varieties are recommended to farmers and cropping guidelines are published (LBL 2003). Beside sugar beet, there are no other sugar crops that are cultivated in Switzerland. Research was carried out some years before to asses the potential of other sugar crops: Agroscope RAC Changins, the Swiss Federal Agricultural Research Station (RAC) proved the potential of **jerusalem artichoke** (*Helianthus tuberosus*) and **sweet sorghum** (S*orghum bicolor*) in the years 1987 to 1990 (Reust and Dutoit 1992). For jerusalem artichoke, a few origins or varieties were tested. The species was considered to be suitable to Swiss conditions until about 1200 meters above sea level. Yields of the tubers were at about 40 t/ha with a dry matter content of approximately 21%. Content of sugar varied between 12-18% of the fresh weight (70-75% of the dry weight). Other agronomic research was carried out on sweet sorghum. The tested varieties or origins showed yields between 27-82 t/ha with a dry matter content of 22-30%. Sugar content of the dried material was between 27-35%. Under Swiss conditions, this thermophil plant should be able to provide up to 6 or 7 t/ha fermentable sugar.

Starch crops

No specific agronomic research exists for starch crops. But for all the potential starch crops such as **wheat** (*Triticum aestivum*), **rye** (*Secale cereale*), **maize** (*Zea mays*) or **potato** (*Solanum tuberosum*) agronomic research on cultivation techniques and variety questions are carried out each year. Guidelines for the cultivation are published regularly by the Swiss Center for Agricultural Extension (LBL 2003). Variety lists are published yearly for wheat and rye (Menzi *et al.* 2003a), maize (Menzi *et al.* 2003b) and potatoes (Hebeisen *et al.* 2002). No starch varieties are included in the variety trials due to the missing starch extracting industry in Switzerland. Varieties with a high content of starch exist. In Germany for example, the breeding company IG Pflanzenzucht developed varieties of potatoes for starch production (http://www.ig-pflanzenzucht.de).

1.1.2 Research for technical use

Agroscope FAT Tänikon, the Swiss Federal Research Station for Agricultural Economics and Engineering (FAT) carried out a test with biologically degradable silage foliage. Different foliages based on plant starch or petroleum were compared. The trial under practical conditions on field was finally carried out only with a petroleum based foliage, but it showed that the foliage started to degrade already after one to three months (Keller 2000).

Other research on starch or sugar based products for technical uses was not carried out in cooperation with the agronomic research stations in Switzerland. It can be supposed that research with plant starch is going on at universities and private companies.

1.2 Industry

Plant starch or sugar can be used in different industrial processes, beside traditional applications such as adhesive agents for board and the production of paper, glaze for the textile industry and washing agents, filler and stabiliser for hygiene articles and plastics and raw material for adhesives and fermentation help, as well for the production of biologically degradable material.

There is no starch processing industry in Switzerland and none is discussed to be built up. For this reason, plant starch processors are not in contact with agronomic research. Starch is purchased abroad. The import statistics shows that there is quite a big quantity of plant starch imported to Switzerland. Most of the imported plant starch is supposed to be used for the traditional applications as mentioned above. Table 1 gives an overview of the imported starch quantities in 2002. Unfortunately, for wheat, maize and potato starch no classification into technical and other uses occurs. For sugar, there is no data available about the imported quantities for technical uses.

Table 1 Imported quantities of plant starch to Switzerland in the year 2002 (without starch for beer production or feeding).

	total [t]	Germany [t]	France [t]	Italy [t]	Netherlands [t]	Belgium [t]	Austria [t]	Denmark [t]	Slovakia [t]	other EU [t]	other countries [t]	Export [t]
Wheat starch	8'703	2'637	593	61	3'317	1'766				312	17	20
Maize starch	11'359	3'236	2'604	865	2'623	617	618		794		2	124
Potato starch	23'170	14'767	2'611		3'085		930	1'769		6	2	1
Maniok starch	289	28			241					1	19	36
Rice starch	429	41	1			373					14	24
Other starch	32	1	1			14		1		1	14	0
Wheat denaturated technical use	101								101			
Rye denaturated technical use	100	100										
Maize technical use	19	4								15		

Source: Swiss Agency for Customs Administration, 2003

About 11,000 t of maize starch are imported, wheat starch is imported in a quantity of about 9,000 t. Most of the starch is imported from Germany. The table shows that potato starch is the most imported starch with a quantity of 23,170 t. This import quantity of potato starch is about half the production of the sole starch extraction company Agrana in Austria (http://www.agrana.com). The company processed in 123 days a quantity of 213,000 t of starch potatoes with a starch content of about 17%.

It was not possible to find all the enterprises in Switzerland working with plant starch due to missing contacts to these enterprises.

One company, working with plant starch, is the company **Petroplast Vinora** (http://www.petroplastvinora.ch) producing and selling packaging. One product line (qualiCOMP®) includes biologically degradable packaging such as bags produced of starch. “CompoBag” is one of the products sold in the Swiss retail business. All these packagings are produced in Switzerland. The raw material “Mater-bi”, a plant starch granulate, is imported from the Italian company Novamont (http://www.novamont.com).

Compared with Switzerland, there are more companies working with plant starch in Germany and Austria: Natura Verpackungs GmbH (http://www.innovation-in-packaging.com) in Germany for example produces and sells compostable packaging made of starch, sugar and other renewable raw materials. In Austria, the enterprise Verpackungszentrum Graz (http://www.vpz.at) produces and sells biogenous packaging, made of starch and sugar. Actually, the company carries out studies for the production of biological plastics made of agronomic waste and surplus.

Switzerland has a sugar production industry but sugar is used only for alimentary use and not for industrial processing. The main sugar factories in Switzerland for sugar extraction from sugar beets are situated in Aarberg and Frauenfeld (http://www.zucker.ch).

1.3 Markets

In Table 2, the acreages for the indigenous production of the imported starch quantities are calculated for Switzerland. The acreages for starch potatoes would be about 2500 ha, about the same surface would be needed for wheat.

Table 2 Estimated surfaces for starch crops, if all the imported starch or denaturated grains for technical uses would be cultivated in Switzerland.

Starch crops	Use	Estimated yields in CH [t/ha]	Starch content [% DM]	Estimated starch yield [t/ha]	Imported tonnes [t]	Estimated surface [ha]
Maize	Starch	8	80	6.4	11,359	1,775
Wheat	Starch	6	65	3.9	8,703	2,232
Potato	Starch	45	20	9	23,170	2,574

DM: dry matter

Unfortunately, it is impossible to carry out a market analysis for sugar for technical uses due to the lack of import data for sugar for technical uses.

1.4 Environmental

Table 3 gives an overview of some environmental impacts of carbohydrate crops in Switzerland. Potatoes and sugar beets are quite intensive cultures with a high need of fertiliser and plant protection products for weed disease control. Rye, wheat and maize are less demanding crops.

Table 3 Survey of some environmental impacts of carbohydrate crops.

	Potato	Maize	Wheat	Rye	Sugar beets
Nitrogen demand [kg/ha] [1)]	120	110	140	90	100
Phosphat demand [kg/ha] [1)]	90	95	65	65	95
Potassium demand [kg/ha] [1)]	410	240	95	115	330
Magnesium demand [kg/ha] [1)]	20	20	15	10	55
Herbicide use [3)]	[symbol][symbol]	[symbol][symbol]	[symbol][symbol]	[symbol][symbol]	[symbol][symbol]
Pesticide use [3)]	[symbol]	-	[symbol]	-	[symbol]
Fungicide use [3)]	[symbol][symbol]	-	[symbol]	-	[symbol]
Erosion potential [2)]	high	high	medium	(low)-medium	high
Water requirement [3)]	(medium)-high	high	medium-high	medium	high

[symbol]: rare to frequent application; [symbol][symbol]: frequent to regular application; ([symbol]): no substances approved; n.s.: not specified
[1)] according to LBL (2003)
[2)] according to Vullioud and Maillard (1998)
[3)] own estimation

Dinkel *et al.* (1996) carried out a life cycle assessment of starch based plastic. They pointed out that the cultivation of potatoes and maize (relative to other cultures) can have a negative influence on soil and biodiversity. The study showed that the use of plant-starch-based plastics can have positive effects on the energy balance and climate protection. But if starch crops are cultivated on additional or new cultivation areas, mainly on near-natural areas, negative impacts on water can occur due to eutrophication. The highest environmental impacts for conventionally (made of non-renewable raw material) produced plastics occur during production and waste management. For plant-starch-based plastics, environmental impacts occur especially during cultivation, processing of basic material and products and sometimes during waste management.

2 Barriers to progress

2.1 Scientific

There is actually no agronomic research on varieties with a higher content of starch in Switzerland. And there is no public research on the use of plant starch for technical uses. Since there are only a few companies working with plant starch, it can be assumed that some research is carried out by these companies.

2.2 Technical issues

There is no starch extraction industry in Switzerland. For this reason, no starch plants are cultivated and all plant starch is bought from abroad by the processing industry. Problems with the processing of plant starch in Switzerland seems to be solved by the processing industry itself, since there are no public research projects known.

2.3 Environmental

Table 4 shows the environmental requirements of starch and sugar crops for cultivation. Due to the fact that potatoes, maize, wheat, rye and sugar beets are often cultivated in Switzerland, environmental conditions will not form barriers for these crops. For starch production it is supposed that grain-maize, winter wheat and winter rye would be used. Environmental requirements therefore are listed up for these crops.

Table 4 Survey of environmental requirements of carbohydrate crops in Switzerland.

	Potato	Grain-maize	Winter wheat	Winter rye	Sugar beets
max. m.a.s.l. [1]	1500	600	800 [2]	1000 [2]	700 [3]
Vegetation period [days] [2]	90-140	150-180	260-280	250-270	160-200
Soil preferred [1]	light (-medium)	medium-heavy	medium-heavy	light-medium	medium (-heavy)
Cultivation break [years] [1]	3	1-2	1	1-2	3
pH soil [1]	4.5-6.5	5.5-7	6-7.5	5-7	6.5-7.5
Performance on dry soil [1]	bad	bad	medium	good	medium [3]

m.a.s.l.: meters above sea level
[1] according to Vullioud and Maillard (1998)
[2] own estimation
[3] according to LBL (2003)

2.4 Legislative issues

There are no special legislative issues concerning starch crops. For maize, wheat, potatoes and rye, varieties have to be listed on the national variety list for seeds to be sold. At the moment, there are no varieties for starch extraction on this list. But in case of an increasing demand for starch production in Switzerland, it should not be a problem to include suitable varieties to this list. Since July 2002 all varieties listed in a national variety list in EU countries have been allowed to be brought to market in Switzerland without being tested in Switzerland.

Actually there is a minimum and maximum amount for indigenous sugar production in Switzerland. The lower limit of the annual sugar amount is 120,000 t and the upper limit is 185,000 t. Additionally, a maximum of 2,000 t of sugar from organic farming can be produced (Zuckerverordnung Art. 1, Ziff.1). But it is intended to cancel this limitation for the harvest 2004.

A barrier to progress for materials based on plant starch could be missing legislative pressures for the use of biodegradable products. Waste management in Switzerland for example is regulated by community. Each community has its own law for waste management. About 80% of the municipal solid waste is burnt in rubbish combustors in Switzerland. In consequence, starch- and sugar-based, biologically degradable products would mostly be burnt as well in rubbish combustors, because there are only few possibilities to compost even biologically degradable products.

2.5 Economic issues

There is no special financial support by government for starch crops. If there were starch or sugar crops cultivated for new industrial use in Switzerland, the crops could profit from the same crop-linked subsidies as “normal” crops such as bread wheat or maize. A general contribution of 1,600 CHF/ha (1,080 €) per year is paid as a direct payment related to surface, independent of the crop. In 1992, a working group (Gantner *et al.* 1992) computed the subsidies that would be required, if Swiss starch was sold at world market prices. The following Table 5 shows the calculation for wheat, starch potatoes and maize.

Table 5 Estimated requirements of subsidies for starch plants in Switzerland in 1992.

	Unit	Wheat	Starch potatoes	Maize
Yield	t/ha	6.5	45	8
Producer price CH	€/t	573	133	487
Income CH	€/ha	3'727	6'000	3'893
World market price free of all charges of duty	€/t	133	73	100
Requirement of subsidies, based on prices of CH	€/ha	2'860	2'700	3'093
	€/t	440	60	387

Source: Gantner *et al*., 1992

The calculation shows that the demand for subsidies for the production of starch plants in Switzerland would be huge. In 2004, the producer prices in Switzerland decreased especially for wheat, therefore subsidies for starch production would be smaller if starch production had to generate the same income than production for nutrition.
As long as no subsidies are paid, Swiss starch is too expensive and industry will buy the starch on the world market. Since these needed subsidies are neither paid nor discussed, no starch production will be economical in Switzerland in the next years.

3 Priorities

Most of the potential starch and sugar crops have been cultivated in Switzerland for food production over many years and cultivation techniques and agronomic characteristics are well known. But actually, there is no specific agronomic research on starch and sugar crops for technical uses. For this reason, it is difficult to give advice on the potentially best carbohydrate crop or variety for technical uses for cultivation in Switzerland. It has to be considered that varieties that can be used for starch production normally are not the same as for food or feed purposes. Special starch potato varieties are known for example in Germany, but not yet tested in Switzerland. Further research for starch and sugar varieties for technical uses would therefore be preferable.

Actually, no starch crops are cultivated in Switzerland, due to the missing extracting industry. Furthermore, there seems to be no interest for starch production in Switzerland. Plant starch is bought from abroad by the processing industry. Plant-starch-based raw materials have to provide at least equal qualities as non-renewable raw materials for plastics. Quality standards have to be fulfilled. Otherwise, plant starch or sugar cannot compete against materials based on mineral oil.

Since there are no starch and sugar crops cultivated for technical uses, there are no associations attending to the interests and needs of farmers and industry partners. Nevertheless, if starch and sugar crops for technical uses were cultivated in Switzerland and extraction and processing industry exist, a good coordination between the partners would be necessary to optimise the value chain from growing to processing.

The Innovation Promotion Agency (KTI) supports research programs initiated by small and medium sized enterprises together with research institutes (see Chapter A). Within these programmes, research and development of materials based on plant starch - for example biologically degradable materials - could be advanced with only a small financial input by interested companies.

Until now, starch and sugar crops can not profit from the crop-linked contribution for renewable raw materials as for example fibre crops do. To advance the use of carbohydrate crops in industry, different ways of supporting can be discussed:

- Crop-linked contribution on the agricultural side to reduce the raw material costs
- financial support for raw materials on the processing side, for example refunded amount per processed kilogram starch or sugar for technical use
- legislative target for substitution of mineral oil based materials by carbohydrate based degradable materials.

All these possibilities are characterised by advantages and disadvantages, especially on the economic view. If materials based on mineral oil should be replaced by biologically degradable materials, it has to be considered that for the maximum ecology benefit waste management has to be adapted for biologically degradable materials. In Switzerland, waste management is regulated on the community level and not nationally. This is the reason why collection and composting of biologically degradable materials is regulated only in some communities.

Furthermore, considering ecological and environmental impacts, production of starch and sugar has to be viewed in a critical way. Potentially negative environmental impacts could reduce the positive aspect of the application of renewable raw materials for the production of biologically degradable materials. Already in 1992, a working group (Gantner *et al.* 1992) showed that additional cultivation of potatoes and maize for starch production should not be recommended due to the intensive cultivation level of these crops. Wheat or rye are supposed to be ecologically more reasonable starch crops.

Cultivation of starch and sugar crops for technical uses as renewable raw materials can be reasonable under two circumstances. First, if the environmental impacts of starch or sugar based products are lower during the whole life cycle than of the equivalent plastic. Secondly, if biological degradability of the plastic product is important, for example in environmentally sensitive areas.

As a conclusion, the following points have to be highlighted: Significance of starch and sugar production for technical uses as renewable raw materials is low in Switzerland. Agronomic and technical research activity is small and there is no starch-extracting industry. The sparsely existing processing industry buys plant starch from other countries. But there are still open questions concerning processing technologies. The choice of adequate starch and sugar crops and possible incentives for their cultivation and processing have to be considered seriously.

D Crops with special uses

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1 Opportunities

The focus of Swiss activities concerning crops with special uses lay on the use and the research on medicinal plants for pharmaceuticals and herbal health products, and plants for the production of essential oils and cosmetics. Cultivation of such crops had been quite important in Switzerland until the end of the second world war. Due to several factors such as liberalisation of imports, low prices for medicinal crops in eastern countries and chemical synthesis of desired substances, cultivation of medicinal plants stopped. Only in 1981 did the cultivation of medicinal plants start again in Switzerland, first on some small acreages in the Poschiavo in the regions of south eastern Switzerland.

There were rarely considerable activities found about plants for dye or plant protection. In the following chapters, an overview of the most important crops with special uses is given. The list doesn't claim to be complete due to the wide range of medicinal and aromatic plant species.

1.1 Science and technology

1.1.1 Agronomic research

Most of the agronomic research activities on crops with special uses are carried out at Agroscope RAC Changins, the Swiss Federal Agricultural Research Station (RAC) and at "Médiplant", a research center in the Valais. This centre was created in 1989 and is dedicated to the studies of medicinal and aromatic plants and their cultivation (http://www.mediplant.ch). At RAC, research on medicinal and aromatic plants started in 1982. The main research at RAC focused from the beginning on the improvement of varieties and selection of varieties adapted to the mountainous regions and their special climatic conditions, and on cultivation techniques. Studies of selection have been performed on about fifteen species. Further research with medicinal and cosmetic plants is going on at universities and some private companies.

Some of the medicinal and cosmetic plant species, on which research in Switzerland mainly focuses, are listed below.

Some plants provide flowers, leaves or roots for the use in the pharmaceutical or cosmetic industry:

- **Marsh mallow** (*Althea officinalis*): Marsh mallow is known for antiinflammatory action on mucous membranes. The plant is used in herb-candys or in the pharmaceutical industry. Roots are mainly processed, additionally leaves and flowers. Studies on cultivation and diseases were made at RAC (Rey 1996, Rey 2002, Carlen 2003, Michel 2003).
- **Podophyllum** (*Podophyllum hexandrum*): Podophyllum has some effects against tumours. Main components of the rhizomes are podophyllotoxin and pelatin that are used by the pharmaceutical industry. Commissioned by a Swiss pharmaceutical enterprise, studies about domestication of this plant are carried out at Médiplant (www.mediplant.ch).
- **Small-flowered willow herb** (*Epilobium parviflorum*): This traditionally not known medicinal plant is said to help in cases of prostate's adenoma. The volatile components of the plant - flavonoids and tannins - are used by the pharmaceutical industry. Delabays and Vergères (1991) showed that cultivation of this plant is possible in Switzerland, although cropping techniques have to be optimised. Delabays *et al.* (1993) published cultivation guidelines. A study of the floral biology has also been undertaken, with focus on the selection of origins with high tolerance to powdery mildew (*Sphaerotheca epilobii*) (Simonnet and Delabays 1993).
- **St. John's-Wort** (*Hypericum perforatum*): St. John's-Wort is cultivated as a result of increasing market demands for anti-depressants. The main active agents hypericins and flavonoids occur in the stade of inflorescence and are used by the pharmaceutical industry. Kartnig *et al.* (1997) investigated questions of cultivation and the amounts of main components. Since domestication and cultivation are challenging, an agronomic research program was started in 1996 at Médiplant (Debrunner and Simonnet 1998).
- **Sage** (*Salvia officinalis*): The leaves of this plant are used in case of inflammations and for cosmetic use. At RAC, questions of cultivation techniques and selection of adapted varieties have been carried out (Rey 1991, Rey 1995).
- **Thyme** (*Thymus vulgaris*): The flowering herbs of thyme have positive effects in case of cough and digestion. A lot of research has been carried out at RAC to find adapted varieties and better cultivation techniques (for example Rey 1990a, Rey 1990b, Rey 1991, Rey 1993).
- **Wormwood** (*Artemisia annua*): This plant produces the antimalarial compound artemisinin. At present, artemisinin can only be produced economically by extraction of the leaves of wormwood plants. The species is suitable to the Swiss climate (Delabays 1990). Several studies were carried out to answer questions of cultivation techniques (Delabays *et al.* 1992; Delabays *et al*. 1994). Breeding activities were started to increase the artemisinin content (Magalhães *et al.* 1996, Magalhães *et al.* 1999, Simonnet *et al.*

2001). Furthermore, Gaudin and Simonnet (2002) compared two methods to detect the content of artemisinin.

- **Sea Buckthorn** (*Hippophae rhamnoides*): The berries of this shrub contain a lot of vitamins C and E, flavonoïds and fatty acids. They are used by the cosmetic industry and in the phytopharmacy sector. Médiplant carried out studies on the domestication and cultivation of this species (Delabays and Slacanin 1995).

Other plant species provide seed oil with different composition of fatty acids. Oils are used in the pharmaceutical and cosmetic industry:

- **Evening primrose** (*Oenothera biennis* or *Oenothera sp.*): The seed oil, rich in gamma linoleic acids, is asked for by the cosmetic and pharmaceutical industry. Commissioned by the cosmetic industry, several studies are carried out at Médiplant to answer questions of cultivation in mountain regions. Breeding activities at Médiplant focus on increasing seed yield (Simonnet and Gaudin 2002).
- **Rose** (*Rosa sp.*): The extracted seed oil of this plant, rich in polyunsatured fatty (linolen acid) acids and tocopherols, has curing effects on the skin and is used in the cosmetic industry. At Médiplant, several studies on the domestication of different species of roses were carried out (Delabays and Slacanin 1995).

The following plant species are rich in essential oils that are used in the pharmaceutical or the cosmetic industry:

- **Purple coneflower** (or samspon flower, *Echinacea sp.*): The plant is used in cosmetic products for skin care. Its main components such as essential oils, alcamids, polysaccharids, esters of cafeic acid, echinolone and betanin are found in the roots and in the whole plant. Purple coneflower is also used in the phytotherapy. Research on the domestication of Purple coneflower is carried out (Delabays and Slacanin 1995).
- **Arnica** (*Arnica montana*): Arnica is a very old medicinal plant still used in the pharmaceutical industry for its antiphlogistic properties. Essential oils, triterpenic alcohols and flavonic heterosids coming from the flowering parts and seeds are the main components used. Cultivation is challenging and studies of natural sites and populations were realised (Delabays 1990). Delabays and Mange (1991) showed that cultivation is possible, even though this medical plant is very sensitive to soil conditions.
- **Hemp** (*Cannabis sativa*): Essential oils are also found in the flowers of hemp. Several studies about the cultivation of hemp were carried out at Agroscope FAL Reckenholz, the Swiss Federal Research Station for Agroecology and Agriculture (FAL) (see chapter B).

Meier and Mediavilla (1998) studied the factors that influence yield and quality of hemp essential oil. Yields of essential oil were highest at seeding rates of 5 kg/ha and when about 50% of the plant had reached maturity. Suitable varieties for essential oil production were identified and published (Mediavilla et al. 1999). Mediavilla and Steinemann (1997) compared essential oils of several industrial and drug varieties for their composition and smell. The study showed that Tetrahydrocannabinol (THC) concentration did not influence the quality of the essential oils.

Further research to answer questions of cultivation techniques and adapted varieties has been carried out for example for the **Edelweiss** (*Leontopodium alpinum*) (Rey and Slacanin 1999a), **white genepi** (A*rtemisia umbelliformis*) (Rey and Slacanin 1997, Rey *et al.* 2002) and **yellowish lady's mantle** (*Alchemilla xanthochlora*) (Rey and Slacanin 1999b). More information about these and other species for medicinal and cosmetic use are available on the internet, for example on:

- http://www.mediplant.ch
- http://www.valplantes.ch
- http://www.inaro.de

Research about the use of special crops as plant protection products is carried out at FAL. Some medicinal plants and their essential oils can be used for example against potato diseases (Krebs and Jäggi 1999, Krebs and Forrer 2001, Krebs 2003). Further research on plant-based plant protection products against *Phytophtera infestans,* causing late-blight disease on potatoes, is carried out (Bassin and Forrer 2001). **Yellow mustard** (*Sinapis alba*) can possibly be used against special wheat diseases (Winter *et al.* 2001).

No considerable research activity and cultivation of plants for dye could be noticed in Switzerland. In Austria, Hartl and Vogl (2000) carried out an extensive work about agronomic questions, research projects and processing of plants for dye in Austria. Also in Germany, information about dyeing plants can be found, for example in FNR (2001).

1.1.2 Technical research

At the Swiss Federal Research Stations, no technical research was carried out. Research on the extraction of active agent is supposed to be examined at pharmaceutical and cosmetic companies.

1.2 Industry

There are several companies in Switzerland processing medicinal plants and producing plant-based pharmaceuticals and cosmetic products. Some of them also carry out research. The following specification lists some of these companies. Due to the fact that some of the firms are quite small, the list cannot be complete.

- **VitaPlant AG** (http://www.vitaplant.ch) represents an independent and efficient service centre for research, development and production of medicinal plants and extracts for the pharmaceutical and food industry. The Swiss company works in several sectors: research of pharmacologically active substances with in vitro bioassays, phytochemical studies, breeding of medicinal plants, development of cultivation techniques and development of extraction technologies.
- The company **Alpinamed AG** (http://www.alpinamed.ch) develops, produces and distributes its own plant-based drugs and produces plant substances (extractions and tinctures) for the pharmaceutical, cosmetic and health food industries on request. Alpinamed works nationally and internationally.
- **Biomed AG** (http://www.biomed.ch) is a commercial enterprise for pharmaceutical products for the Swiss market. It trades with plant-based drugs and mineral drugs and doesn't carry out own research.
- The company **Bioforce** (http://www.bioforce.ch) produces plant-based and homeopathic drugs, cosmetic products and some dietary aliments. Bioforce cultivates about 45 different species of medicinal plants on 15 ha. About 4 ha are cultivated by respecting the guidelines of organic farming. In addition to cultivation, wild growing plants are also collected.
- The enterprise **Weleda** (http://www.weleda.ch) produces pharmaceutical and cosmetic products by respecting the pharmaceutical and therapeutic guidelines of the anthroposophic concept of Rudolf Steiner. Most of the medicinal and aromatic plants are cultivated by respecting the biological dynamical guidelines. A certified collection of wild growing plants provides other species for the production.
- Cough drops made of Swiss herbs are a traditional speciality produced by the Swiss firm **Ricola** (http://www.ricola.ch). Marsh mallow is an important ingredient for the production of these cough drops. About 200 farms have contracts with Ricola for the cultivation of medicinal plants. The company also produces teas with Swiss herbs and medicinal plants.

- The small company **Soglio** (http://www.soglio-produkte.ch) produces and sells cosmetic products with plant ingredients grown usually in Soglio (a village in the Swiss mountains). Plants are cultivated or wild growing plants are collected.
- A farmer in West-Switzerland produces hemp oil by using industrial hemp varieties. The oil is sold in the United States as skin care product (Prêtre 2004).
- The company **Valchanvre** (http://www.valchanvre.ch) sells several hemp products such as essential oils and cosmetic products.
- A few companies in Switzerland focus on the extraction of plant material for the production of plant-based pharmaceuticals or cosmetics.
- **Alpaflor** (http://www.alpaflor.ch), a Swiss company established in the Valais, is specialised in the cultivation, extraction and isolation of Swiss alpine plants to produce exclusive, high-quality functional extracts for the production of plant-based cosmetics. The plants grow in the valaisian mountains of the Swiss alps.
- The **Bassins distillerie** (http://www.bassins.ch/DistillerieBassins/DistilBassins.htm) is a main producer of essential oils in Switzerland. They produce essential oils of medicinal and aromatic plants. Plants are also cultivated.
- Some of the farmers cultivating medicinal plants are organised in associations or cooperatives. These aim at assuring quality of the raw material and to improve the marketing of the cultivated plants.
- **ArGe Bergkräuter** is an umbrella organisation of several farmer cooperatives of producers of medicinal and aromatic plants in Switzerland. Its aim is the promotion of the cultivation of herbs in mountain areas. It coordinates the work of the cooperatives, is looking for new markets and contracts and has a supervisory role.
- **Valplantes** (http://www.valplantes.ch) is one of these farmer's cooperations, situated in the Valais mountains. Farmers cultivate medicinal plants and herbs respecting the guidelines of organic farming. More than 150 farmer families belong to this association. They grow more than 40 plant and herb species.

1.3 Markets

Cultivation areas of medicinal and cosmetic plants in Switzerland are small. In the official statistic of the Swiss Federal Statistical Office, medicinal or cosmetic plants are registered together with aromatic plants for alimentation. Due to this fact, the acreages of medicinal or cosmetic plants cannot be identified.

Table 1 shows the acreages of medicinal and aromatic plants since 1990. In 2002, the cultivation area was about 220 ha. Before 1990, medicinal plants were included in the variable "remaining cultivated land" and from 1999 they have been divided into annual and perennial medicinal and aromatic plants.

Table 1 Cultivated areas of medicinal and aromatic plants in Switzerland since 1990 (start of the statistical registration for medicinal and aromatic plants).

	1990	1995	1996	1997	1998	1999	2000	2001	2002
Annual medicinal and aromatic plants [ha]	-	-	-	-	-	89	88	53	71
Perennial medicinal and aromatic plants [ha]	42	66	86	111	142	99	125	161	150
Total	42	66	86	111	142	187	213	214	220

Source: Swiss Federal Statistical Office, 2003

Acreages have been increasing for some years, mainly because of higher market demands for plant-based products, especially if they are produced after certified organic farming guidelines. With the increasing acreages, production has also increased. A statistic of the Swiss Farmers Association shows a small, but continuously increased production of 263 t in 2000 (Table 2).

Table 2 Production of medicinal and aromatic plants in Switzerland since 1986.

	1986	1990	1995	1996	1997	1998	1999	2000	2001
Medicinal and aromatic plants, dried [t]	100	53	120	145	169	167	198	263	280

Source: Swiss Farmers Association, 2003

In 2001, the "ArGe Bergkräuter" registered for its cooperatives a production of about 170 t of medicinal and aromatic plants on a surface of about 65 ha (ArGe Bergkräuter 2002). The registered orders lay higher, at about 210 t of plants.

About 50 species of medicinal and aromatic plants (including herbs for alimentation) are cultivated in Switzerland after certified organic farming guidelines on a surface of 130 ha (Carlen 2003). Of this, marsh mallow (*Althea officinalis)* for example is cultivated on a surface of 6 ha. Dried roots of marsh mallow have a market of about 10 t per year in Switzerland (Rey 2002).

The import statistics (Table 3) gives information about some plants, parts of plants or essential oils that are supposed to be used for medicinal or cosmetic uses. The official import statistic doesn't document separately all essential oils or plant-based cosmetics and pharmaceuticals. Concerning the pharmaceutical sector, there is no overview available about imported and exported plant-based medicaments. Therefore, the import statistics can only give an idea about quantities needed in Switzerland.

Table 3 Imported quantities of some plants, parts of plants and essential oils for possible medical, cosmetic or other special uses in the year 2002. Exports are negligible.

	Total [t]
Plants, parts of plants, seeds and fruits from plants for medical uses, insect repellents, pest control and from other species for similar uses	4701
Peppermint oil (*Mentha piperita*)	122
Mint oils (except *Mentha piperita*)	90
Liquorice roots (fresh or dried)	6
Lavender oil	204
Ginseng roots	23

Source: Swiss Agency for Customs Administration, 2003

There is too little information and no central database available to carry out a realistic market analysis.

1.4 Environmental

Due to the wide range of cultivated medicinal and cosmetic plants in Switzerland, it is not possible to summarise the potential impacts on the environment by cultivating these plants. For further assessments, information can be found in the cultivation recommendations of RAC and Médiplant and in the literature cited before in chapter 1.1.1.

2 Barriers to progress

2.1 Scientific

Even though there is a lot of research done actually, there is still a lack of knowledge about cultivation and possibilities of pharmaceutical or cosmetic plants. Not all of these plants can be domesticated and cultivated easily. Diseases for example are an important barrier to progress for some species. Further agronomic research is needed.

St. John's-Wort for example doesn't need special climatic or soil conditions (Büter 1997). But domestication and cultivation are challenging. Actually, plants are not perennial enough for a successful cultivation. Commissioned by the Swiss firm Bioforce/TG, trials of Médiplant have determined that diseased plants of St. John's-Wort suffer from an anthracnosis caused by the soil fungus *Colletotrichum gloeosporioïdes* (http://www.mediplant.ch; Darbellay, 2000).

2.2 Technical issues

Technologies for the extraction of the plant ingredients depend on the plant species. Due to missing information about the technologies, it is not possible to list up technical problems. Extraction and processing technologies are supposed to be object of further research in public institutes and the pharmaceutical and cosmetic industry.

2.3 Environmental

Most of the medicinal and aromatic plants need special climatic or soil conditions for successful cultivation in Switzerland. Due to the large number of Mediterranean species among medicinal and aromatic plants in Switzerland, several studies on winter protection are carried out at RAC.

Diseases for example can also limit cultivation. Arnica for example is very sensitive to soil conditions. Its cultivation should be on acid land, free of lime and apparently not too rich in phosphates (Delabays and Mange 1991). Regarding the pests, Delabays and Mange (1991) observed the fungus *Entyloma arnicale* infecting the leaves and the diptera *Tephritis arnicae*. Emery *et al.* (1995) carried out studies on the biology of this insect and possibilities to protect Arnica by an anti-insect net.

Cultivation of sensitive species such as Arnica is restricted to specific regions in Switzerland. Arnica, originally grown in mountain areas, is mostly cultivated in the Valais mountains, a region with drier and warmer climate.

2.4 Legislative issues

There are no special legislative issues for the cultivation of plants with special uses in Switzerland. Even for hemp, there are no restrictions. All varieties can be cultivated, even if they contain THC. Hemp cultivation is only punishable if flowers are used as drugs (BetmG Art. 1, Ziff. 2). Cultivation of drug hemp could be interesting for the production of essential oils, since these varieties were bred for a high yield of flowers, in contrast to fibre hemp.

Plant protection products are rarely registered for medicinal or cosmetic plants due to the small acreages of single plant species.

2.5 Economic issues

Plants with special uses are not labelled as renewable raw materials in Switzerland. Other renewable raw materials such as fibre or oil crops can profit from crop-linked contributions. Only hemp can profit from these crop-linked contribution of 1,500 CHF/ha (1,000 €) if the chosen variety is registered on the Swiss hemp variety list (Sortenkatalog-Verordnung, annex 4). But in either case, a general contribution of 1,600 CHF/ha (1,080 €) per year is paid as a direct payment related to surface, independent of the crop.

Prices of cultivated medicinal plants are normally higher than those of plants collected in their natural habitat. Naturally grown plants are mostly collected in countries with lower salaries (Büter 1997). For pharmaceutical products, cultivated plants are preferable to plants collected in nature, due to less variations of active agents concentrations and other reasons. The cultivation of medicinal plants in Switzerland has still a much lower importance compared with neighbour countries like France, Austria and Germany. Higher production costs in the Swiss companies could be the main reason for this decline.

3 Priorities

Many already used and potential medicinal plants are known in Switzerland. Research is carried out continuously on agronomic questions, such as cultivation techniques, plant protections, diseases, selection of varieties and about domestication of potential medicinal species. A lot of this research is especially done at RAC and at the research center Médiplant.

In Switzerland, the whole value chain from research, production, transformation and commercialisation works quite well in the sector of medicinal plants. A lot of research is carried out, and the research center Médiplant works close to practice also due to contracts with several pharmaceutical or cosmetic companies. Farmers are organised in associations and cooperatives and have close contacts to industry. These cooperatives also create innovative ideas.

Thus, the market for medicinal and aromatic plants is well organised. The system is based on an intensive collaboration between all participants, such as scientists, producers and industry. This whole value chain is well organised so that the production of medicinal and aromatic plants can be financially interesting for farmers, even if medical plants cannot profit from a crop-linked contribution in Switzerland.

Cultivation of medicinal and aromatic plants has continuously increased for the last 20 years. Nevertheless, the cultivation of medicinal and cosmetic plants in Switzerland still has lower significance than in other European countries. Medicinal plants cultivated in eastern countries or the Mediterranean region can be produced much more cheaply than in Switzerland. Therefore, the only possibility for further increase of the cultivation and significance of medicinal and aromatic plants consists in cultivation after organic farming guidelines. Acreages of medicinal and aromatic plants cultivated after organic farming guidelines are increasing continuously as well, because there is a lot of interest in organically produced products. Actually, chances and possibilities for cultivation of medicinal and aromatic plants are good and cultivation could still increase.

Further help and incentives for increasing the cultivation could be given by the government. If medicinal and cosmetic plants could be categorised officially as renewable raw materials and if their cultivation would thus profit from contributions, the significance of the cultivation of these plants in Switzerland could increase even more.

Cultivation of medicinal and aromatic plants is not expected to have negative impacts on the environment. In the contrary, a lot of the cultivated plants are cultivated after organic farming guidelines. Furthermore they are often cultivated in mountain areas and quality standards are high.

As a conclusion, cultivation of medicinal and aromatic crops is increasing and can be attractive in Switzerland, but the only possibility for being competitive against countries with lower production costs is by cultivating after organic farming guidelines. Especially with the upcoming enlargement of the European Union, medicinal plants with low prices cultivated in east European countries can be brought to the Swiss market. Nevertheless, if the well organised network between research, farmers and industry remains, cultivation of medicinal and aromatic plants can continue to increase.

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http://www.alpaflor.ch

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http://www.bassins.ch/DistillerieBassins/DistilBassins.htm

http://www.bioforce.ch

http://www.biomed.ch

http://www.inaro.de

http://www.mediplant.ch

http://www.ricola.ch

http://www.soglio-produkte.ch

http://www.valplantes.ch

http://www.vitaplant.ch

http://www.valchanvre.ch

http://www.weleda.ch

ANNEXES

Annex 1: Crop areas in Switzerland (1)

	1975	1980	1985	1990	1996	1997	1998	1999	2000	2001
	area [ha]	area [ha]	area [ha]	area [ha]	area [ha]	area [ha]	area [ha]	area [ha]	area [ha]	area [ha]
open arable land	261 022	273 077	286 653	312 606	308 924	300 738	299 361	293 947	292 548	290 222
grain, total	177 723	176 784	183 767	211 845	196 438	186 373	186 867	182 257	182 669	179 576
bread grain										
wheat	86 205	85 226	92 829	97 228	96 547	95 432	95 917	92 861	94 109	89 682
rye	6 196	8 058	3 751	3 440	6 697	3 973	3 367	3 433	3 643	3 284
spelt, emmer, einkorn etc.	3 563	5 100	4 054	2 605	3 956	2 174	1 542	1 221	1 467	2 020
meslin of bread grain	183	220	148	115	223	172	136	27	41	33
feed grain										
barley	44 675	46 081	50 457	60 004	51 059	48 115	49 020	48 942	45 741	43 845
oats	13 318	11 117	9 840	10 422	7 993	8 157	7 198	5 866	5 067	3 923
triticale			803	10 476	6 395	7 523	8 101	8 049	10 306	12 217
maize	21 546	20 385	21 560	27 321	22 916	20 244	21 046	21 647	22 006	24 329
meslin of feed grain	2 074	651	324	233	650	583	540	211	291	244
pulses										
beans			663	159	319	350	398	270	275	300
peas			-	1 676	2 015	2 955	2 468	2 680	2 581	2 924
lupins									36	51
root crops										
potatoes	23 811	23 664	19 976	17 764	16 666	14 962	13 883	13 740	14 153	13 785
sugar beed	10 641	13 075	14 246	13 783	16 045	16 727	16 675	17 450	17 725	17 757
fodder sugar beet	2 636	1 853	2 569	3 598	4 069	3 895	3 625	3 239	2 897	2 531
outdoor vegetable										
outdoor vegetable	9 154	8 196	7 757	6 596	8 121	8 474	8 076	8 189	8 459	8 390

Annex 1: Crop areas in Switzerland (2)

	1975	1980	1985	1990	1996	1997	1998	1999	2000	2001
	area [ha]	area [ha]	area [ha]	area [ha]	area [ha]	area [ha]	area [ha]	area [ha]	area [ha]	area [ha]
oil seeds										
oilseed rape	9 283	12 577	14 529	16 461	13 998	14 745	15 168	14 865	13 112	12 019
soya			-	1 051	1 840	2 341	2 884	2 273	952	467
sunflower							1 396	1 776	3 554	4 541
silage- and green maize										
silage- and green maize	27 119	37 412	42 199	38 797	43 352	42 279	40 997	40 475	40 486	41 268
others										
tobacco	713	769	719	677	734	693		696	681	680
other arable crops	1 369	469	228	199	5 326	6 944		7 816	8 559	10 524
bedding and peat land			4 238	5 274	6 935	7 213		6 413	7 157	7 270
other use			3 535	5 252	5 492	5 538		7 695	6 374	6 096
grass land										
artifical grass land	102 634	106 406	117 560	90 319	111 133	113 865	113 116	115 933	115 490	118 544
natural pastures, meadows	558 058	561 311	636 822	634 719	628 976	627 457	632 428	626 799	629 416	627 338
horticulture										
grapes	11 563	12 327	12 287	12 403	13 107	12 531	12 839	12 921	13 223	13 443
fruit tree planting	7 207	7 528	7 147	7 336	7 703	7 724	7 816	7 786	7 857	7 850
berries			650	581	606	662		403	426	369

Annex 1: Crop areas in Switzerland (3)

	1975	1980	1985	1990	1996	1997	1998	1999	2000	2001
	area [ha]	area [ha]	area [ha]	area [ha]	area [ha]	area [ha]	area [ha]	area [ha]	area [ha]	area [ha]
renewable raw materials										
miscanthus (chinese reed)				3	275	280	290	267	267	255
oilseed rape					1 410	1 513	1 477	1 576	1 231	1 115
hemp					4	1	4	105	144	114
kenaf					45	4	49	-	-	-
sunflower					43	1	1	20	25	38
flax / linseed					12	9	18	-	-	-
medicinal and aromatic plants, total				42	86	111	142	187	213	214
annual medicinal and aromatic plants								89	88	53
perennial medicinal and aromatic plants								99	125	161

Annex 2: Crop yields in Switzerland (1)

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
	yield [t]	yield [t]	yield [t]	yield [t]	yield [t]	yield [t]	yield [t]	yield [t]	yield [t]	yield [t]
grain, total	1 022 671	930 485	910 945	1 190 284	1 374 743	1 235 836	1 273 639	1 182 771	1 252 968	1 213 738
bread grain, total	552 825	495 650	465 930	565 608	656 801	569 106	608 199	562 713	614 797	597 147
winter wheat	472 793	427 729	406 951	499 880	584 735	518 880	549 006	505 631	520 247	521 276
summer wheat	40 571	35 455	28 628	33 669	35 689	20 709	25 016	20 957	45 931	35 410
wheat, total	513 365	463 184	435 578	533 550	620 424	539 589	574 022	526 589	566 177	556 686
spelt	19 487	13 788	12 150	14 077	15 545	12 046	9 367	8 286	7 352	9 506
rye	19 287	18 434	17 798	17 653	20 655	16 882	24 548	27 504	40 986	29 826
meslin of bread grain	686	243	404	328	177	589	262	334	282	1 130
feed grain, total	469 846	434 835	445 014	624 676	717 942	666 730	665 440	620 058	638 170	616 591
winter barley	198 302	172 374	191 501	236 548	293 472	288 839	297 495	307 585	318 666	234 077
summer barley	62 886	51 112	42 614	54 184	54 338	43 936	47 293	40 173	48 771	50 555
barley, total	261 189	223 486	234 115	290 733	347 810	332 775	344 789	347 758	367 437	284 632
oats	49 964	29 172	36 963	46 725	58 395	53 021	54 597	50 803	52 890	50 447
meslin of feed grain	1 521	1 531	1 783	1 715	1 716	1 142	1 367	1 015	716	1 837
maize	152 499	168 554	139 418	232 052	247 915	225 915	220 517	186 710	186 916	249 434
triticale	4 673	12 092	32 735	53 451	62 106	53 878	44 170	33 773	30 212	30 242
pulses, total	3 014	3 753	5 043	5 735	6 509	7 479	8 685	10 814	8 767	8 632
peas	2 219	3 357	4 580	5 332	6 131	6 697	8 270	10 231	7 738	7 720
beans	794	396	463	404	377	782	414	584	1 029	912
root crops, total	1 867 608	1 710 923	1 752 640	2 100 419	2 066 799	2 084 634	1 942 843	2 039 480	2 125 983	1 750 278
potatoes	866 700	724 500	673 200	832 500	795 600	771 300	721 800	756 900	773 100	570 600
sugar beets	788 900	761 300	823 874	922 479	888 251	973 885	896 446	907 270	976 439	841 404
fodder sugar beets	199 048	208 323	242 046	327 600	364 748	321 089	309 757	359 310	357 324	318 666
others	12 960	16 800	13 520	17 840	18 200	18 360	14 840	16 000	19 120	19 608

Annex 2: Crop yields in Switzerland (2)

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
	yield [t]	yield [t]	yield [t]	yield [t]	yield [t]	yield [t]	yield [t]	yield [t]	yield [t]	yield [t]
oil seeds, total	39 085	40 174	49 096	49 989	54 310	45 826	54 113	49 378	53 700	39 602
oilseed rape	39 085	40 174	49 096	49 989	54 310	43 215	50 492	44 635	49 579	34 643
sunflower	-	-	-	-	-	-	-	-	-	296
soya	-	-	-	-	-	2 611	3 621	4 743	4 121	4 663
renewable raw materials										
oilseed rape (grains)	-	-	-	-	-	-	-	-	-	107
kenaf (dry matter)	-	-	-	-	-	-	-	-	207	158
sunflower (grains)	-	-	-	-	-	-	-	-	-	16
hemp (dry matter)	-	-	-	-	-	-	-	-	-	60
miscanthus (dry matter)	-	-	-	-	-	-	-	-	-	518
grapes, total	162 310	175 762	163 654	151 908	227 712	173 942	178 298	163 685	151 812	155 400
red grapes	57 869	69 987	59 812	71 063	89 003	71 338	77 709	74 278	71 733	70 460
white grapes	104 441	105 775	103 842	80 845	138 709	102 604	100 589	89 408	80 080	84 940
others										
tobacco (dried leaves)	1 496	1 747	1 305	1 530	1 571	1 106	1 365	1 173	1 437	1 318
vegetable	297 531	278 154	262 839	325 455	313 216	313 449	306 809	298 351	289 414	276 951
medicinal and aromatic plants (dried)	...	100	76	18	35	53	77	92	101	120

Annex 2: Crop yields in Switzerland (3)

	1995	1996	1997	1998	1999	2000
	yield [t]	yield [t]	yield [t]	yield [t]	yield [t]	yield [t]
grain, total	1 245 612	1 317 471	1 194 083	1 240 975	1 028 482	1 169 464
bread grain, total	654 591	710 205	608 559	625 548	513 442	591 129
winter wheat	577 159	626 335	557 347	578 222	457 828	543 591
summer wheat	22 438	17 758	15 173	15 876	31 624	17 573
wheat, total	599 597	644 093	572 520	594 098	489 452	561 164
spelt	12 625	20 760	11 092	8 326	5 507	7 314
rye	41 223	43 914	23 971	22 306	18 348	22 404
meslin of bread grain	1 146	1 438	976	817	135	247
feed grain, total	591 021	607 266	585 524	615 427	515 040	578 335
winter barley	264 056	290 482	275 618	296 804	223 314	256 414
summer barley	30 264	32 372	28 870	32 928	27 377	17 693
barley, total	294 320	322 854	304 488	329 732	250 692	274 107
oats	42 805	44 736	45 337	39 855	27 710	26 295
meslin of feed grain	2 855	3 662	3 167	2 979	968	1 462
maize	218 132	196 500	187 727	191 813	192 338	212 391
triticale	32 909	39 514	44 805	51 048	43 332	64 080
pulses, total	8 990	10 215	13 414	11 235	10 118	10 091
peas	7 882	8 717	11 981	9 675	9 192	8 954
beans	1 108	1 498	1 433	1 560	926	1 137
root crops, total	1 704 455	2 319 299	2 223 430	1 993 644	1 935 176	2 284 548
potatoes	568 800	812 000	687 000	560 000	484 000	600 600
sugar beets	823 955	1 142 199	1 180 030	1 124 644	1 186 176	1 408 448
fodder sugar beets	289 000	348 000	339 000	293 000	250 000	258 000
others	22 700	17 100	17 400	16 000	15 000	17 500

Annex 2: Crop yields in Switzerland (4)

	1995	1996	1997	1998	1999	2000
	yield [t]	yield [t]	yield [t]	yield [t]	yield [t]	yield [t]
oil seeds, total	50 910	50 820	59 154	58 771	50 830	54 476
oilseed rape	45 056	44 265	50 020	47 167	38 315	39 060
sunflower	1 006	1 822	2 937	4 090	4 962	11 666
soya	4 848	4 733	6 197	7 514	7 553	3 750
renewable raw materials						
oilseed rape (grains)	4 038	4 279	5 161	4 806	3 998	3 682
kenaf (dry matter)	300	200	19	0	0	0
sunflower (grains)	88	120	6	0	58	145
hemp (dry matter)	40	110	60	200	270	250
miscanthus (dry matter)	1 500	2 000	2 050	2 700	2 400	2 300
grapes, total	154 732	170 863	137 105	153 374	171 017	166 825
red grapes	71 554	83 057	65 962	73 956	79 845	81 807
white grapes	83 178	87 806	71 143	79 418	91 172	85 018
others						
tobacco (dried leaves)	1 594	1 659	1 039	1 506	1 103	1 182
vegetable	307 162	343 160	346 073	319 089	300 668	310 278
medicinal and aromatic plants (dried)	120	145	169	167	198	263

Annex 3: Useful Internet-links

http://www.carmen-ev.de	C.A.R.M.E.N. Centrales-Agrar-Rohstoff-Marketing- und Entwicklungs-Netzwerk e.V.
http://www.fnr.de	Fachagentur Nachwachsende Rohstoffe e.V.
http://www.inaro.de	Informationssystem Nachwachsende Rohstoffe
http://www.nachwachsende-rohstoffe.info	Nachrichten-Portal für Nachwachsende Rohstoffe
http://www.industrialcrops.eu.com	European portal for chemicals from biomass
http://www.ienica.net	IENICA Interactive European Network for Industrial Crops and their Applications
http://www.nf-2000.org/home.html	BioMatNet: Biological Materials for Non-Food-Products
http://217.148.32.203/home.asp	INFORM Industry Network for Renewable Resources and Materials
http://www.nnfcc.co.uk	National Non-Food Crops Centre
http://ecocrop.fao.org	Ecocrop
http://www.bagkf.de/sofa	Seed Oil Fatty Acids
http://www.biofibre.net	Biofibre.net – a Nordic biofibre network
http://www.ibaw.org	IBAW – International Biodegradable Polymers Association & Working Groups

Annex 4: Contact database (1)

Organisation	Address	Telephone	Fax	Email
Oil				
2 B Bioreffinery AG	Bachstrasse 29, 8912 Obfelden	+41 043-333 9536	+41 043-333 9537	info@2bio.ch
Auro AG	Rüfenacht & Baumann AG, Parkstraße 1, 2575 Täuffelen	+41 32 396 08 08	+41 32 396 08 00	info@ ruba-paint.ch
Bucher AG Langenthal Motorex Schmiertechnik	Postfach, 4901 Langenthal	+41 62 919 75 75	+41 62 919 75 95	info@motorex.com
Omya AG	4665 Oftringen	+41 62 789 29 29	+41 62 789 20 77	info.ch@omya.com
Fibres				
Innovative Bio Fibre AG (IBF)	Lerchenfeldstr. 5, 9014 St. Gallen	+ 41 71 274 71 80	+ 41 71 274 71 81	welcome@ibf-ag.ch
NAPAC	Ebnet, Postfach 609, 8370 Sirnach	+41 71 969 14 14	+41 71 969 14 15	info@napac.ch
Carbohydrates				
PetroplastVinora AG	Postfach, Feldrietstrasse 8, 9204 Andwil	+ 41 848 811 001	+ 41 848 811 002	info@pev.ch
Special use				
Alpaflor	Engelgasse 109, 4052 Basel	+41 61 706 49 06	+41 61 706 49 07	-
Alpinamed AG	Alte Landstrasse 11, 9306 Freidorf	+41 71 454 70 80	+41 71 454 70 88	admin@alpinamed.ch
ArGe Bergkräuter				bergkraeuter@mails.ch
Bioforce	9325 Roggwil TG	+41 71 454 61 61	+41 71 454 61 62	info@bioforce.ch
Biomed AG	Überlandstrasse 199, 8600 Dübendorf	+41 1 802 16 16	+41 1 802 16 00	biomed@biomed.ch
Distillerie de Bassin	1269 Basssin	+41 22 366 15 46	+41 22 366 15 43	distillerie_de_bassins@bluewin.ch
Médiplant	Centre des Fougères, 1964 Conthey	+ 41 27 345 35 11	+ 41 27 346 30 17	mediplant@rac.admin.ch
Ricola	Postfach 130, 4242 Laufen	+41 61 765 41 21	+41 61 765 41 22	info@ricola.ch
Soglio-Produkte	7608 Castasegna	+41 81 822 18 43	+41 81 822 18 43	mail@soglio-produkte.ch
Valchanvre GmbH	Châble Bet 22 , 1920 Martigny	+41 27 723 23 28	+41 27 723 23 38	info@valchanvre.ch
Valplantes, Farmers Association				
VitaPlant AG	Benkenstrasse 254, 4108 Witterswil	+41-61-722 10 90	+41-61-723 98 26	info@vitaplant.ch
Weleda	Stollenrain 11, 4144 Arlesheim	+41 61 705 21 21	+41 61 705 23 10	cverdy@weleda.ch

Annex 4: Contact database (2)

Organisation	Website	Areas of interest	Market sector
Oil			
2 B Bioreffinery AG	http://www.2bio.ch	Fibres, Proteins	Industrial, Commercial
Auro AG	http://www.ruba-paint.ch, http://www.auro.de	Oil	Industrial, Commercial
Bucher AG Langenthal Motorex Schmiertechnik	http://www.motorex.ch	Motor oils, Hydraulic oils	Industrial, Commercial
Omya AG	http://www.omya.ch	Oil	Industrial, Commercial
Fibres			
Innovative Bio Fibre AG (IBF)	http://www.tebo.ch/ibf/deutsch/home.htm	Fibres	Industrial, Commercial
NAPAC	http://www.napac.ch	Fibres	Industrial, Commercial
Carbohydrates			
PetroplastVinora AG	http://www.petroplastvinora.ch	Starch	Industrial, Commercial
Special use			
Alpaflor	http://www.alpaflor.ch	Pharmaceuticals, Essential Oils, Cosmetics	Agriculture, Industrial
Alpinamed AG	http://www.alpinamed.ch	Pharmaceuticals, Cosmetics, Personal Care Products	R&D, Industrial,Commercial
ArGe Bergkräuter		Pharmaceuticals, Cosmetics, Personal Care Products, Essential Oils	Agriculture, Commercial
Bioforce	http://www.bioforce.ch	Pharmaceuticals, Cosmetics, Personal Care Products	Agriculture, Industrial, Commercial
Biomed AG	http://www.biomed.ch	Pharmaceuticals	Industrial, Commercial
Distillerie de Bassin	http://www.bassins.ch/DistillerieBassins/DistilBassins.htm	Essential Oils	Agriculture, Industrial, Commercial
Médiplant	http://www.mediplant.ch	Pharmaceuticals, Essential Oils, Cosmetics, Personal Care Products	R&D
Ricola	http://www.ricola.ch	Pharmaceuticals	Agriculture, Industrial, Commercial
Soglio-Produkte	http://www.soglio-produkte.ch	Cosmetics	Agriculture, Industrial, Commercial
Valchanvre GmbH	http://www.valchanvre.ch	Essential Oils, Cosmetics	Commercial
Valplantes, Farmers Association	http://www.valplantes.ch	Pharmaceuticals, Cosmetics, Personal Care Products, Essential Oils	Agriculture, Commercial
VitaPlant AG	http://www.vitaplant.ch	Pharmaceuticals	R&D, Industrial, Commercial
Weleda	http://www.weleda.ch	Pharmaceuticals, Cosmetics, Personal Care Products	Agriculture, Commercial, Industrial

Annex 4: Contact database (3)

Organisation	Address	Telephone	Fax	Email
Public Reserach				
Agroscope FAL Reckenholz, Swiss Federal Research Station for Agroecology and Agriculture	Reckenholzstr. 191, 8046 Zürich	+41 1 377 71 11	+41 1 377 72 01	info@fal.admin.ch
Agroscope FAT Tänikon, Swiss Federal Research Station for Agricultural Economics and Engineering	Tänikon, 8356 Ettenhausen	+41 0 52 368 31 31	+41 0 52 365 11 90	info@fat.admin.ch
Agroscope RAC Changins, Swiss Federal Agricultural Research Station	CP 254, 1260 Nyon 1	+41 22 363 44 44	+41 22 362 13 25	info@rac.admin.ch
Institute for Manufacturing Automation, at the Swiss Federal Institute of Technology (ETH)	Zürich	+41 1 632 23 65	+41 1 632 11 69	institut@texma.org
Swiss Federal Laboratories for Materials Testing and Research (EMPA)	Überlandstrasse 129, 8600 Dübendorf	+41 44 823 55 11	+41 44 821 62 44	contact@empa.ch

Annex 4: Contact database (4)

Organisation	Website	Areas of interest	Market sector
Public Reserach			
Agroscope FAL Reckenholz, Swiss Federal Research Station for Agroecology and Agriculture	http://www.reckenholz.ch	Fibres, Oils, Starch and Carbohydrates	R&D
Agroscope FAT Tänikon, Swiss Federal Research Station for Agricultural Economics and Engineering	http://www.fat.ch	Fibres	R&D
Agroscope RAC Changins, Swiss Federal Agricultural Research Station	http://www.racchangins.ch	Oil, Starch, Plants with special uses	R&D
Institute for Manufacturing Automation, at the Swiss Federal Institute of Technology (ETH)	http://www.texma.org	Fibres	R&D
Swiss Federal Laboratories for Materials Testing and Research (EMPA)	http://www.empa.ch	Fibres	R&D