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The Faculty of landscape Planning, Horticulture and Agriculture Science
Plant Breeding and Biotechnology

Angelica archangelica L.

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Abstract

Angelica archangelica (Garden angelica) is the only Medicinal and Aromatic Plant (MAP) with a Nordic origin. The plant can reach up to three meters when cultivated. *Angelica archangelica* is used as flavouring in additives, honey, beverage base, essential oils, folklore medicine and as ornamental for decorative purposes. Commercial cultivation is mainly focused on root production. Production countries are Poland, Netherland, France, Belgium, Switzerland, and former Czechoslovakia with an overall yearly world production of 1000 kg of essential oils. Compounds to be found in *A.archangelica* are bittering agents, essential oils, flavonoids, tanning agents, resins, silica, carbohydrates, coumarins, organic acids and terpenes. Essential oils derived from angelica root are composed of over 60 different constituents. β−phellandrene and α−pinene have the highest concentration in root oil but sabiene, myrcene, limonene, 3−carene and p−cymene are also found in large amounts.

In year 2000 the global market of herbal products was US$ 60 000 million. Developing countries are the main producer of MAP in the world, but the largest market is in developed countries, especially Europe. Interests of locally produced MAPs are growing, and advantages of having a European production are many. A Scandinavian production could be possible, but also problematic, since facts differ greatly in studied literature. The purpose of this thesis was to write a literature study about *A.archangelica*, and let a forgotten plant be reintroduced in Scandinavia. There is definitely a great need of more research concerning *A.archangelica*. There is no ongoing commercial production of *A.archangelica* in Scandinavia, except on Iceland.

Key words: *Angelica archangelica* L.,subsp. *archangelica*, subsp. *litoralis*.

Sammanfattning

Angelica archangelica(kvanne) är den enda nyttoväxten med ett nordiskt ursprung. Växten kan bli upp till tre meter när den odlas. *Angelica archangelica* används som smakämne i mat– och spritindustrin, örtmedicin och även för dekorativa syften. Kommersiell odling är främst inriktad på rotproduktion. Odling finns i Polen, Holland, Frankrike, Belgium, Schweiz, och f.d. Tjeckoslovakien med en årlig världsproduktion av 1000 kg eterisk olja. Innehåll i *A.archangelica* är bitterämnen, eteriska oljor, flavonoider, garvämnen, harts, kiselsyra, kolhydrater, kumariner, organiska syror och terpener. Eteriska oljan från roten är sammansatt av över 60 olika komponenter. β–phellandren och α–pinen har högst koncentration i rotoljan, men sabinen, myrcen, limonen, 3–caren and p–cymenfinns också i höga koncentrationer.

År 2000 hade världens örtmedicinmarknad ett värde på US$ 60 000 miljoner. Utvecklingsländer producerar den mesta MAPs i världen, medan den största marknaden finns i industriländer, främst Europa. Intresset för inhemskt producerade MAPs växer och det finns många fördelar med att ha en europeisk produktion. En skandinavisk produktion bör vara möjlig, men med många problem, eftersom fakta som undersökts har skiljt sig nämnvärt mellan varandra. Syftet med denna uppsats var att skriva en litteraturstudie om *A.archangelica* en glömd kulturväxt, att återintroduceras i Skandinavien. Det behövs mycket mera forskning angående *A.archangelica*. Det finns i dagsläget ingen kommersiell odling av *A.archangelica* i Skandinavien, förutom på Island.

Nyckelord: Angelica archangelica L.,subsp. *archangelica,* subsp. *litoralis*.

Table of Content

1 Introduction

Angelica archangelica L. (garden angelica) is the only utility plant with a Nordic origin (Galambosi 1994). It has been used in Nordic countries as a medicinal plant since ancient times and travelled south with the monks when Scandinavia became Christianised (Karlsson Strese 2008) around 829−830 A.D. to 1100 A.D. (Gräslund 1994). Sami have used the plant both for medicinal and food purpose (Fjellström 1964). In the Scandinavian countries the plant has kept its native name “kvanne” (Almark 2006, Virtuella floran 2009), but in the rest of the world the name could be derived from a legend where an archangel told monks about its many medicinal property (Karlsson Strese 2008).

A.archangelica is a member of Apiaceae family, which contains many known aromatic kitchen plants. Main signature for Apiaceae besides aromatic features is the umbel−like inflorescence structure (Jacobsen & Jensen 1999b). A.archangelica is an immense plant (Hegi & Beger1926, Krok & Almquist 2003, Mossberg & Stenberg 2003), cultivated it can reach up to three meters (Hegi & Beger 1926, Lindholm 2003). In wild habitat they reach a height of 50−100 cm (Nyman 1980, Thurzová 1983, Starý & Jirásek 1999, Mossberg & Stenberg 2003).

Preferred growing media is a humid and nutritious soil that can be easily washed off from the roots after harvest (Heeger 1989, Galambosi 1994). The plant is a pioneer, both in wild habitat and cultivated, and is usually one of the first plant visual during the season and is not sensitive to temperatures under 0°C (Hornok 1992).

Angelica is mainly grown for its essential oil in the roots, which is used in food, alcohol and medicinal industry (Wiersema & León 1999). Roots contain 0.5−1.0%, fruits 0.6−1.5% and leaves contains 0.2−0.3% of essential oils (Hornok 1992, Galambosi 1994). The world yearly production of *A.archangelica* essential oil is 1000 kg and countries producing are Poland, Netherland, France, Belgium, Switzerland, and former Czechoslovakia (Dachler & Pelzmann 1999) and Germany (Charbonneau et al. 1993).

The purpose of this thesis was to gather information about *A.archangelica* L. to get an overview of this medicinal and aromatic plant that has strong Nordic connection, both to culture, history and agriculture. Another purpose of this thesis was to rediscover this plant, since its ability to withstand frost and therefore perhaps be of interest for a Scandinavian production.

2 Material and Methods

This bachelor thesis is done as a pure literature study, meaning there has been no practical part involved. Information and sources are taken mainly from books and reports, to cover as much possible over *A.archangelica* L. Sources, especially reports, have been taken primarily from Lund University. The library in Alnarp, a part of the Swedish University of Agricultural Science, has been an important source collector as well. Some of the most important sources covering cultivation of medicinal and aromatic plants (MAP) are from Germany and collected at Humboldt University in Berlin, since they are no longer available at any Swedish or Nordic library. Important and narrow information about cultivation practices of *A.archangelica* can be found on Internet from the German state.

The report is divided into sections, where Production (10) is the largest part. The headline includes both studies made and cultivation advises for *A.archangelica* L.

3 Botany

3.1 Apiaceae (Umbelliferae)

Apiaceae (Carrot family) is a family which is known for many often used kitchen plants, e.g. carrot (*Daucus carota*), dill (*Anethum graveolens*), coriander (*Coriandrum sativum*), celery (*Apium graveolens*), parsley (*Petroselinum crispum*), fennel (*Foeniculum vulgare*) and as well as garden angelica (*Angelica archangelica*). Main characteristic for Apiaceae is the inflorescence, which is gathered in compound umbels, a parasol–like inflorescence, which gave its former family name Umbelliferae which still can be seen used. The umbels are composed of small flowers, with white or yellow colour of the petals. All parts of the plant have resin canals containing essential oils. The stem is often hollow and can be swollen at the nodes. Leaves are arranged spirally and have often inflated leaf sheaths (Jacobsen & Jensen 1999b) as seen on *A.archangelica*. The fruit is a schizocarp and will split into two one–seeded mericarps (Jacobsen & Jensen 1999b, Hickey & King 2000).

3.2 Angelica

All angelicas are immense species, in height as well as leaf size (Hegi & Beger 1926, Krok & Almquist 2003, Mossberg & Stenberg 2003). They are perennial plants that often are monocarpic (Jacobsen & Jensen 1999a) which means that they will die after the flowering and fruiting has ended (Jacobsen & Jensen 1999a, Hickey & King 2000). A normal life cycle of angelica is completed in three years, but sometimes when seedlings are good developed it can be fulfilled in only two years (Grieve 1979).

Leaves are large, 2–3 pinnate with wide lobes (Hegi & Beger 1926, Tutin 1968, Nyman 1980, Jacobsen & Jensen 1999a, Krok & Almquist 2003, Mossberg & Stenberg 2003) and at the plane stalk which is violet at the base (Mossberg & Stenberg 2003) the petioles are enlarged and inflated (Hegi & Beger 1926, Tutin 1968, Nyman 1980, Krok & Almquist 2003, Mossberg & Stenberg 2003). Inflorescence is convex with a lot of small flowers gathered with white, greenish or pink petals and even sometimes yellowish (Hegi & Beger 1926, Tutin 1968, Jacobsen & Jensen 1999a). Fruit is compressed which gives an oblong to ovate or oblong shape (Hegi & Beger 1926, Tutin 1968) with four wings (Jacobsen & Jensen 1999a) and visual ridges (Hegi & Beger 1926, Tutin 1968).

3.3 *Angelica archangelica* L.

Syn: *Archangelica officinalis* (Moench) Hoffm. (Wiersema & León 1999).

Described as a large perennial herb with an upright stem with sometimes purple features which can reach up to 300 cm in gardens (Hegi & Beger 1926, Lindholm 2003), and from 50−100 cm in wild habitat (Nyman 1980, Thurzová 1983, Starý & Jirásek 1999, Mossberg & Stenberg 2003). During the period of growth *A.archangelica* is giving off a pleasant scent that is unusual and is distinguishing for the plant. Both the upper part of the plant and the roots are fragrant with this special scent. Roots are turnip−shaped (napiform) in wild habitat and shorter and with more adventitious roots in conventional growing (Hegi & Beger 1926). Moreover roots are thick (see fig. 1) and heavy (Hegi & Beger 1926, Grieve 1979, Nyman 1980, Sandberg & Göthberg 1998) and internal flesh is yellow to white and with a yellowish milky sap (Hegi & Beger 1926).

Figure 1. Root of *A.archangelica* L. (Forsnäs Hemman och Malgomajuddens gård 2009a).

From the root a round arm−thick, straight stem is developing and can reach up to three meters. The stem is hollow, glabrous and green but with streaks of red (Hegi & Beger 1926). On the stem the large leaves (60−90 cm) are situated. Leaves are 3−pinnate (sometimes 2) and oblong−ovate, acutely serrate and situated with a simple terminal (Tutin 1968). The leaves are strongly sheathing at the base of the petioles (Tutin 1968, Sandberg & Göthberg 1998). Leaflets are lancet−shaped, ca 5 to 8 cm long (Hegi & Beger 1926).

At the top of the stem the inflorescence is a compound umbel. The diameter of the whole inflorescens is reaching from 8 up to 15 cm or more (Hegi & Beger 1926) and each umbel contains of 20–40 small flowers. Petals are green and yellowish (Hegi & Beger 1926, Mossberg & Stenberg 2003) and with bracteoles that are as long as the petals (subsp. *archangelica*) where subsp. *litoralis* bracteoles are about half as long as petioles (Hegi & Beger 1926, Tutin 1968).

The flowering period is during July−August (Hegi & Beger 1926, Starý & Jirásek 1999, Mossberg & Stenberg 2003). Yellow fruits are matured from the flower (Hegi & Beger 1926, Grieve 1979). There are two subspecies distributed in Sweden, *A.a.*subsp. *litoralis* and *A.a.*subsp. *archangelica* (Ljungkvist 2007). They mainly differ in taste quality, where *A.a.*subsp. *litoralis* has a more pungent taste than the milder subsp. *archangelica* (Tutin 1968, Nicolaisen 1980). Differences can also be seen on the fruit. Fruits size in subsp. archangelica is 5−6 x 4−5 mm, fruit being almost oblong. The dorsal ribs are prominent and acute, but in subsp. *litoralis* the dorsal ribs are not prominent. The size of the fruit is also smaller, 5−6 x 3.5−4.5 mm (Hegi & Beger 1926, Tutin 1968). The chromosome number is 2n=22 (Tutin 1968).

Figure 2. Illustrated *A.archangelica* from Köhler's medicinal plants (1887).

4 Distribution and habitat

Angelica archangelica has a very interesting historical and cultural distribution pattern: the plant being one of very few medicinal plants that have been spread from the north to the south, the opposite of what normal MAPs do. The plant is said to have its origin from the northern part of the world, and has been travelling to the Central and Southern Europe to become established and widely neutralised as a domestic plant with the help of monks (Ljungkvist 2007). The native origin is northern Europe, Eastern Europe, northern Asia and Greenland (Wahlin & Blixt 1994).It is believed that the plant came to the United Kingdom in 1568 from northern latitudes (Grieve 1979).

The two subspecies, subsp. *archangelica* and subsp. *litoralis*, vary not only in their morphology but they also differ distribution and habitat. Subspecies *archangelica* is more common in the northern parts of the world, in Central and Western Europe, Greenland, Northern and Eastern Europe to eastern Siberia. In Asia it is common in eastern Middle Asia to the Himalaya and often naturalised throughout Europe where it has been cultivated (Hanelt 2001).

Looking at fig. 3 (a), the presence of subsp. *archangelica* in Scandinavia particular in Sweden is in the mountainous region, with outcrops along coniferous forest and rivers (Wahlin & Blixt 1994). According to Nya Nordiska Floran (Mossberg & Stenberg 2003) habitat for *A.a.*subsp. *archangelica* is sections where the snow has not been melted even though its summer and the area around are snow−free[1]. It is also found in areas where moisture is abundant along rivers, brooks and wells. Meadows, willow thickets and screes are as well a natural habitat for the *A.a.* subsp.*archangelica* (Mossberg & Stenberg 2003). Subspecies *litoralis* is abundant in most of the coasts of northern Europe (Sweden, Denmark, Finland, Norway, Island, Faroe Islands), in northern Germany and Balkan (Hanelt 2001, Mossberg & Stenberg 2003) which has a seashore habitat, with stony grounds and open landscape (Wahlin & Blixt 1994) (see fig.3(b)).

[1] Swedish: Snölegor

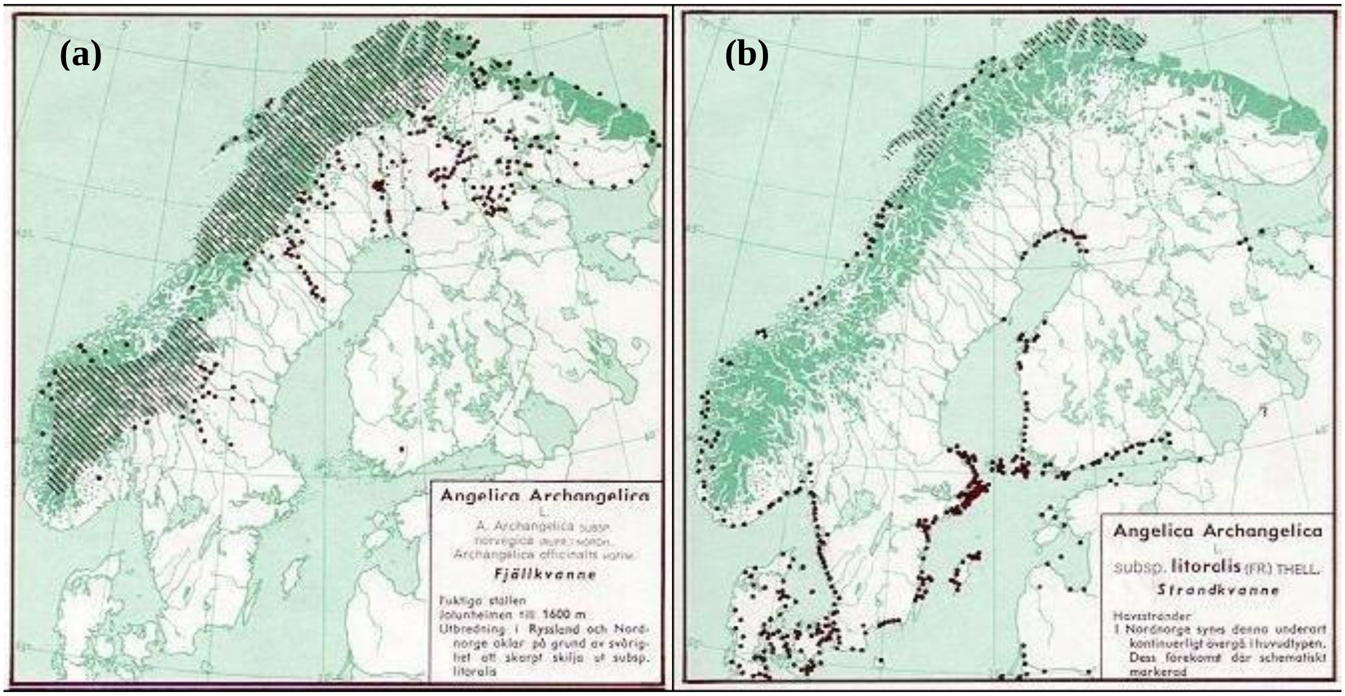

Figure 3. (a). Distribution of *A.archangelica* subsp. *archangelica* on Scandinavia Peninsula. (b). Scandinavian Peninsula showing the distribution of the *A.a* subsp. *litoralis* (Hultén 1950).

5 History and Etymology

This Old Norse plant has been a common vegetable and medicinal herb for the Sami population. Even so, writings give information about the early usage of the plant among the Scandinavian people (Fjellström 1964).

The scientific name that Linné stated in 1753 in his Species Plantarum got the name angelica, a name which had probably been in use since Middle age (Nyman 1980). Even though Linné was Swedish, *A.archangelica* did not make the Swedish or the rest of Scandinavian population to start using itas common name for the plant as in other European countries. In Swedish herbals during 14th century, *A.archangelica* was named herba Angelica, mainly because the books were often translated from other languages (Almark 2006). Scandinavian people kept the native and indigenous names, which in Norwegian is Kvann, in Swedish Kvanne, in Danish Kvan, and in Iceand and Faroe Islands it is called Hvönn and Hvonn, respectively, as written in table 1 (Almark 2006, Virtuella floran 2009).

In Norway, Greenland and Faroe Islands, some districts are even named after *A.archangelica*, e.g., Kvanndal and Kvannfjell in Norway and Kvanefjeld on Greenland (Hegi & Beger 1926, Almark 2006).

Table 1. Common names for A.archangelica (Almark 2006).

Language	Common name
Swedish	Kvanne, angelika, ärkeängelsört, ängelört, lappgräs
Norwegian	Kvann, kvönn, kvenne, kvannrot, kvanngrass
Danish	Kvan
Icelandic	Hvönn, tihvönn (*A.a.* subsp.*litoralis*)
Faroese	Hvonn, hvann, heimahvonn (=when cultivated)
Old Norse	Hvonn, hvönn pl. hvannir
Sami	Faddno (fadno or fattno), påsko (posko)
Finnish	Väinönputki
English	European angelica, garden angelica, wild parsnip, archangel, holy ghost
German	Echte Engelwurz, Geistwurzel, Angelika, Arznei−Engelwurz, Engel−Brustwurz, Therialwurzel, Giftwurzel, Heiliger Geist (Thüringen)
French	Angélique, achangélique, herbe du Saint−Esprit
Italian	Angelico, angelica di Boemia, angelica domestica

5.1 History of Medicinal Use

The knowledge of using *A.archangelica* as a medicine has been known since ancient times, which is understood when reading about the history of the plant, where even the name is connected to the curable properties of the plant. In year 1628 a Swedish medical doctor published a book on herbs called “En myckit nyttigh Örta−book” (Rydaholms Hembygdsförening 2005). He lists eight various virtues that angelica could be good and used for. He notes that angelica should be efficient against e.g. gout and above all the plague. By making angelica water of leaves, stalks and roots the finest water was obtained and could cure more than just the plague. Cystitis, lung and stomach problems, fever and colic are other diseases that could be cured by angelica (Månsson Rydaholm 1987). Linné frequently quotes this book in his herbal written the next century (Rydaholms Hembygdsförening 2005). Later Grieve (1979) states that the same parts are still in use during the 20th century, with an exception of the fruits, that was now included as an important part for both medicinal and commercial use. Fruits are mentioned to contain medicinal properties (Grieve 1979).

The native people of northern Scandinavia, the Sami, have always been using *A.archangelica* (Fjellström 1964).Outside the Sami culture, angelica was a plant that was well known to prevent and to cure scurvy. This was said to be because of angelicas high vitamin C content, but this fact is today revised as angelica do not contain excessively much vitamin C (Dragland 2000).

A.archangelica was given to the cows to make them come to the rutting period (Dragland 2000).

Sources tell that *A.archangelica* was of economical importance for the pharmacopoeias in Norway during the 16th century (Fjellström 1964).

So why did Linné name the plant *Angelica archangelica*? The name had been in use before Linné,and it had thisname already 1683 in Til−Landz' Icones (Nyman 1980). The name has its origin from when the Nordic countries started to become Christianised (Karlsson Strese 2008) around 829−830 A.D. to 1100 A.D. (Gräslund 1994) and monks travelled around the world carrying with them seeds, recipes and knowledge to cure and ease people. Monks were the ones who spread and collected important medicinal plants that could cure ill people. But when the monks reached Scandinavia they had problems to find anything that was of interest to further distribute to the rest of Europe, until they found *Angelica archangelica*. This plant was quickly praised and could almost cure anything. Monks understood the value of the plant and wanted to list it in the convents medicinal herbal selection but by doing so they first needed the blessing of the pope. During the travel south towards the Pope, Gabriel the archangel revealed himself and preached of the medicinal value of the plant (Karlsson Strese 2008).

The name could be derived from another religious legend, which is connected to flowering of *A.archangelica*, around the 8th of May, the day of Michael the archangel apparition. Because of symbolic the plant was said to be exceptional good to keep bad spirits away and was effective against spells and enchantments and the root was highly appreciated and termed “The Root of the Holy Ghost” (Grieve 1979). Additionally, a further archangel, Rafael, revealed himself and spoke about all good effects, from being cure to the plague to give the user of the plant a long life (Almark 2006).

A.archangelica is said to originate from the Greek word aggelos. Homeros and Herodotos used it in the meaning of heavenly messenger or ambassador. The meaning of angel was not connected to the word until much later, the same for the name of the species, archangelica. In Latin the name was missing during the ancient world but in middle age Latin it was abundant as the adjective archangelicus. Corneliuson (2000) further proves that *Angelica archangelica* is connected to Christianity, with the epithet archangelica, which means the archangels plant. The epithet litoralis, means growing on sea shores.

The etymology reveals many parts of *A.archangelica's* history. First found written source dates back to Norway and legislative assemblies Gulating year 1164 and Frostating year 1274. During that time these legislations included growing crops as *A.archangelica* and onion but included as well protection of cultivated area. If an angelica field was subjected of trespassing from a man, it was perfectly acceptable to knock him and steal his clothes (Dragland 2000).

According to Grieve (1979) it is said to be the secret of some wine which have a flavour of Muscatel grape, but it is not mentioned what kind of wines that it refers to. During history of time sugar has been hard to find, but *A.archangelica* has been known and used as a substitute. Used parts working as a natural sweetener was stem, which contains most sugar. Stem parts are mostly used for preserving fruits whereas seeds are used in beverage industry for a more bitter and aromatic taste.

As medicine use *A.archangelica* was first mentioned in Harpestreng’s *H. H.s danske Lægebog fra det 13. Aarhundrede* from year 1244. Since then *A.archangelica* has been mentioned as a medicinal plant. It was said to be the best cure for the plague in Milano during 1510 and was widely used for that purpose. During 1400th and 1500th century Norwegian population traded *A.archangelica* throughout the world, and was the only one doing so, until about two hundred years ago, when Norway started to import instead of exporting the plant (Dragland 2000).

6 Commercial use

Listed in World economic plants (Wiersema & León 1999) *A.archangelica* is used as flavouring in additives, honey, beverage base, essential oils, folklore medicine and as ornamental for decorative purposes.

Garden angelica has as a unique scent that is found in all parts of the plant. Grieve (1979) define the aroma of the dried roots as “strong and fragrant, and the taste at first sweetish, afterwards warm, aromatic, bitterish and somewhat musky” and fresh root can be replaced with musk benzoin. Furthermore. *Archangelica* scent has a touch of oranges and leaves are said to have a firm liquorices taste (Dragland 2000).

Because of the unique scent, angelica has been used since ancient times as a traditional flavouring for confectionary, liqueurs (Grieve 1979), perfumes and wines (Duke 1987), where most of today’s production of *A.archangelica* goes to the beverage production. For the liqueurs Benedictine and Chartreuse roots and seeds are being used to give a special taste, as the same for some particular gin and vermouth. In Norway native liqueurs as St. Sunniva, St. Halvard and Faun are flavoured with *A.archangelica* (Dragland 2000).

Perfume industry in Paris and Cologne values the essential oil from angelica, which are extracted from the root tip as the most aromatic content is highest there (Dragland 2000).

7 Sami

The Sami population has been using *A.archangelica* as an important vegetable and medicinal plant. They have several different names for the plant which gives an indication of how important *A.archangelica* must have been for them and how much they adored it and used it during the months when *A.archangelica* was available for them (Fjellström 2000).

Several words was, and is still, used by Sami and this made Linné a bit confused when he tried to gather information about the plant's botany and practice. *Botsko* and *fatno* were two names he found for the plant. Finally he realised that even the different plant parts of *A.archangelica* had different names. As for the first year plant Sami names the root of *A.archangelica* for *Urtas* and the leaves are named *fadno*. *Fadno* is changed when the plant reaches two years, to *posko*. Dried stems are called *rasi*, meaning grass in Sami, Linné writes in year 1732 (Fjellström, 2000).

For Sami culture all over the Lapp region angelica had two important purposes, as food delicacy and as medicine. Parts used for medicinal application was mainly the root, which was air–dried and thereby conserved and could be used during the whole winter. Angelica root was used more as a prophylactic drug than as a curative to already broken out sicknesses, even though usage for that did take place too, as with treating catarrh (catarrhosi affectus). Furthermore, it was often used for diseases or infections in the stomach and helped Sami to process the often heavy carnivorously eating habits. Even Linné writes 1739 during his travel in Lapland, how convinced he was that angelica helped his stomach during his journey in Lapland, where he only ate the food that the Sami served him (Fjellström 1964).

Sources describes how Sami used small pieces of dried angelica roots to protect themselves against colds and diseases when they during times met many new people (and by that new viruses and bacteria), as when visiting markets or on journeys. By having a piece of angelica between the teeth they believed that they could avoid foreign diseases (Fjellström 1964, Svanberg 1998). Today it is clear that the Sami, which most of the year lived remote and usually only met their family and tribe, had weak resistance (Fjellström1986b).

Fjellström (1986b) states that angelica was taken especially for stomach diseases but also moreover for scurvy, colds, coughing and all sorts of infections. Angelica was seen to be good for preventing almost everything. Fjellström writes that cooked angelica was used against different ache in the body as a poultice.

7.1 Food

Except medicinal use, Sami population used *A.archangelica* as a vegetable. The plant was the first edible plant that could be used as vegetable after a rough winter with no fresh herbs or fruits. It was said to be a Sami delicacy.

Fjellström (1986a) writes more in detail about the Sami use of *A.archangelica*. Breeding and raising reindeer livestock is central in the Sami culture and tradition and all parts of the reindeer was used and taken care of. Reindeer milk was highly appreciated and required preservative methods to be able to store during long winters. Most common way to preserve the milk was to make cheese with different herbs existing in the Scandinavian alpine flora. Reindeer milk is very fat and has high content of milk protein casein, which makes it possible to curdle into cheese without use of rennet. The cheese is called many different names depending on preparation method; e.g. at what time the *A.archangelica* is harvested, which parts of the plant is used and when it was eaten by the Sami people. Sami calls the cheese *gompa* or *kombo* when it’s made from inner parts of the stem of *A.archangelica* and collected during the spring. The chopped stem parts were cooked together with the reindeer milk, which coagulates quickly and is consumed during the summer and wintertime, until next spring. It could besides from stalks be made from buds of the flower umbels. For spring use coagulated cheese is poured into kegs, *kide−piäbmo* or when poured into reticulum and dried outside its called *talve−piäbmo* for winter purpose. When ready it has similarities with today’s cottage cheese with greenish appearance and is used like butter, spread on bread.

The cheese did not only serve to fill the peoples stomachs, but worked was believed to be an important vitamin C source for the Sami when there was nothing fresh and green to eat. *Gompa* was used by the poor Sami, which did not have any reindeer livestock and therefore no access to rennet (Fjellström 1986a).

Nyman (1980) notes that *Angelica archangelica* was used as a culinary delicacy by the Sami, especially young stalks eaten as a dessert or raw on wanderings in the Scandinavian Alps (see fig. 4). It was also used as a substitute for tobacco (Nyman 1980), where the particular smoke of the plant is said to keep away the wolves. Also Swedes and Norwegians smoked *A.archangelica* during times when tobacco was hard to get hold of (Ljungkvist 2007). Linné describes how much the Sami appreciated the stalks, and how they pulled off the outer parts of the stalk before eating it. Linné himself was found of the plant (Linné 1986).

Figure 4. Sami children from Umby, Tärnafjällen, eating and taking care of harvested *Angelica archangelica* ssp. *archangelica* (Forsnäs Hemman och Malgomajuddens gård 2009b).

8 Medicinal use today

Today, angelica is used against inappetence, constipation, coughing, skin diseases, haemorrhoids, inflammations, cramps, ulcer, digestive troubles, menstruation troubles, rheumatism, urination disorders and flatulence. Parts used for pharmacology is Angelicae radix (root) and semina (seeds). (Wahlin & Blixt 1994).Use of angelica as a drug is extended with herb (Herba), leaves (Folia), flowers (Flores), fruits (Fructus) according to Thurzová (1983).

Duke (1987) suggests that *A.archangelica* is an abortifacient, carminative, diaphoric, diuretic, emmenagogue, expectorant, spasmolytic and stomatic. The reputation that angelica should be an abortfacient is not completely proven, but warnings during pregnancy and lactation is done, and the amount of *A.archangelica* should not exceed the daily intake (Newall 1998). Tea made from roots of *A.archangelica* has been used as a folk remedy for stomach cancer (Duke 1987).

New areas for use of *A.archangelica* as a medicinal herb is found while the plant contains furocoumarins, which is a group of special interest for pharmacologists and the drug market. Furocoumarins are used to cure different skin diseases, e.g. psoriasis, vitiligo and T−cell lymphoma (cancer). Today, treatment of PUVA photo chemotherapy (psoralen plus UVA) is used to treat some of the above mentioned skin diseases. Psoralen is counted as a furocoumarin but has properties, which sometimes causes undesirable side effects, whilst being mutagenic and carcinogenic together with UV−light. This is caused by psoralen's ability to interfere with DNA and cause cancer. Here, an isoster of the furocoumarin angelicin which is found in *Angelica archangelica* is suggested to be taking the role of psoralen, and thus giving a more safe treatment for patients with skin diseases. Biggest advantage with using isosters of angelicin in order to find treatment of psoriasis is that it is unable to cross−link with DNA, and therefore decrease severe toxic side effects in PUVA treatments (Barraja et al. 2009).

Other research showing angelicas phytomedicinal value, demonstrate that leaf extract of *A.archangelica* has antiproliferate activity in vitro and antitumour activity in vivo on mice, which could be seen by a reduction in growth of mouse breast cancer cells (Sigurdsson et al. 2005). Same university and institute prove in another article that two of the furanocoumarins found in tincture from fruits of *A.archangelica,* imperatorin and xanthotoxin, are the reason for the antiproliferative activity (Sigurdsson et al. 2004). Hensel et al. (2007) report of *A.archangelica* having properties influencing on human keratinocytes, human liver cells and adhesion of Helicobacter pylori on the human stomach.

Decocted *A.archangelica* seems to have further good influences on the liver, where angelica is cytoprotective and indirectly protects the liver from oxidative stress, which can arise from excessive alcohol impact (Yeh et al. 2003).

A study made in Poland wanted to determine and compare the anticonvulsant and acute adverse (neurotoxic) effects of imperatorin and osthole with valproate, a drug used as a classical antiepileptica (Luszczki et al. 2009). Both imperatorin and osthole are constituents in root oil from *A.archangelica* (Ojala, 1986b). They found that these two natural coumarins could be potential drugs used instead of valproate to suppress seizure activity, and could also be used as parent compounds for further modification to possess even stronger anticonvulsant activity (Luszczki et al. 2009).

9 Constituents

Compounds to be found in *A.archangelica* are bittering agents, essential oils, flavonoids, tanning agents, resins, silica, carbohydrates, coumarins, organic acids and terpenes (Wahlin & Blixt 1994), where in table 1 the major contents are listed. Most important components are the bittering agent angelicin and essential oils. Angelicin is a coumarin, which is said to give the medicinal futures as increased appetite and stomachic to angelica (Dragland 2000). Essential oils derived from angelica root are composed of over 60 different constituents, where 19 of the most frequent are monoterpene hydrocarbons (see Table 2). β−phellandrene usually has the highest concentration in the oil, followed by α−pinene. Sabiene, myrcene, limonene, 3−carene and p−cymene are also found in high amounts (Ojala 1986b).

Ojala (1986) found that the amount of total oil content of the angelica root differed between growing seasons, but the composition remained unchanged. The 19 compounds were for some samples up to 70% of the total oil content, whereas in other samples it was only 50%, depending on where the samples came from. In the case of 3−carene there was a clear cohesion with the amount of concentration together with the latitude the samples came from, the higher latitude, the higher concentration and vice versa (Ojala 1986b).

Compounds in the essential oils are the reason for the complex aroma of angelica. It is said that a high concentration of α−pinene and β−pinene gives a turpentine−like aroma, which is not preferred. A better aroma is contained by having a high concentration of β−phellandrene and a low concentration of the pinenes (Ojala 1986b).

Table 2. The major constituents of Angelica archangelica root after Newall (1998) with exception of essential oils, which are taken from Ojala (1986b) and show the 19 most common compounds from angelica root oil.

Constituents of *A.archangelica*	
Coumarins	Angelicin, osthol, bergapten, imperatorin, oreoselone, oxypeucedanin, umbelliferone, xanthotoxin, xanthotoxol.
Essential oils	α−pinene, camphene, β−pinene, sabiene, 3−carene, myrcene, α−terpinene, limonene, β−phellandrene, cis−β−ocimene, γ−terpinene, trans−β−ocimene, p−cymene, terpinolene, α−copaene, bornyl acetate, 4−terpineol, tridecanolide, pentadecanolide.
Other constituents	Archangelenone (a flavonoid), palmitic acid, sugars (fructose, glucose, sucrose, umbellife-rose),

9.1 Toxicity

Angelica is not seen as a toxic plant (Duke 1987, EMEA 2007), but it can be common with confusion because of the similarities of other plants in Apiaceae which can be toxic to humans (Thurzová 1983). Constituents in *A.archangelica* can be evaluated toxic to humans. When the plant sap is exposed to the sun, it evokes photodermatitis because of the furocoumarins 5−methoxypsoralen (5−MOP) and 8−methoxypsoralen (8−MOP) (Duke 1987, EMEA 2007). Coumarins can be a problem as well when medicating together with anticoagulation treatment (Newall 1998), which is due to the coumarin properties of reducing the coagulation of the blood (Schenk 2008a). During pregnancy intake of angelica should not exceed normal food intake (Newall 1998).

In 2007 the European Medicines Agency (EMEA) and its committee on herbal Medicinal Products (HMPC) evaluated the risks associated with furocoumarins contained in preparations of *A.archangelica*. The report is only focused on the coumarin−derivates that can cause photo toxicity, something which has not been clearly investigated and was requested by a member state of the European Union to clarify for authorities dealing with evaluation of herbal medicine safety. Information collected can be used as a guide by companies for application for marketing authorisation or registration. The report identifies different exposure levels where toxic risks are absent or not relevant. EMEA collects evidences that 8−MOP, 5−MOP and angelicin are genotoxic and induce several different carcinogenic properties in human body. Risk factors of preparations of *A.archangelica* are therefore both photogenotoxic and photo carcinogenic. EMEA states that furocoumarins is also found in e.g. celery and has therefore been calculated before in different countries, and estimation of an average daily intake of 1.45 mg of dietary furocoumarins with high−expose peak up to 14 mg. At these high levels and with addition of UV irradiation toxicity can be observed but is still considered to be No Observable Adverse Effect Level (NOAEL). EMEA reveals in this review many information gaps and uncertainties regarding research of herbal medicines and furocoumarins, and information regarding this group is just assumptions and has not been scientifically proved. EMEA propose a risk−management. Firstly based on TTC[2], where "a daily intake for total furocoumarins in an herbal medicinal preparation that is equal or below 15 µg would not be considered to pose any unacceptable risk to consumers". Secondly based on the comparison with dietary exposure, "a daily exposure of 1.5 mg furocoumarins through herbal medicinal products is not considered to contribute significantly to the overall risk". But in this case there should be warnings for pregnant and co−factors (UV−light). Thirdly and last, for preparations with more than 1.5 mg furocoumarins per day a detailed risk/benefit assessment is necessary and must be made (EMEA 2007). Interesting to know, no documented human studies for angelica have been done (Newall 1998).

[2] Treshold of Toxicological Concern

10 Production

Medicinal and aromatic plants (MAP) are produced in many countries (Schippmann et al. 2002). In 2000 the global market of herbal products was US$ 60 000 million (WHO 2003). The market for MAP is lucrative. Medicinal plant species being produced worldwide is 52 885, with India and China producing the highest number of plant species. Developing countries are producing the main MAP of the world, but the largest market is in developed countries, especially Europe. Germany is one of the main leading importers of the world countries (4th place) but is at the same time a large exporter (3rd place) of MAP (Schippmann et al. 2002). Germany import about 90% of the raw material of MAP and the German market value of herbal medicine is ca 3 Billion € (Bomme 2009).

A.archangelica is a plant commercially cultivated mainly for its aromatic root (Dragland 2000) and is highly valued in food and liqueur industry (Ebert 1982). When considering growing *A.archangelica* for commercial use, it is of high value and importance to know what to harvest, because of large differences in e.g. harvest depending of part of the plant. Even leaves, stalks and fruits can and are sometimes produced (Dragland 2000). These plant parts may contain similar amount of essential oil but oil from roots is seen as the most valuable (Simon et al. 1984). Roots contain 0.5−1.0%, the fruits 0.6−1.5% and the leaves contains 0.2−0.3% of essential oils (Hornok 1992, Galambosi 1994). Production countries are Poland, Netherland, France, Belgium, Switzerland, and former Czechoslovakia (Dachler & Pelzmann 1999) with an overall yearly world production of 1000 kg of essential oils (Galambosi 1994). Germany has a production too but not as large as the above mentioned countries (Charbonneau et al. 1993). Ebert (1982) reports of a German angelica production in year 1978 of 50.4 tons, with a value of 92 000 Euro. Since then the production has been reduced. In Germany 2003 *A.archangelica* was produced on 3.04 hectare. Hyssop, tarragon and black radish are produced in the same amount as angelica in Germany. This can be taken in consideration with German yearly production of parsley, which is the most cultivated aromatic and medicinal herb in Germany, with its 1748 hectares (Hoppe 2005). Ecological production of angelica root in Germany is small, only 0.04 hectares, and with only one producer south−west of Germany in Baden−Württemberg (Röhricht et al. 2003). Scandinavian production seems only to be existing on Iceland (Sagamedica 2009).

10.1 Temperature

As being one of the earliest cultivated pioneers of the season, leaves can be visual already in February, depending on the amount of snow. By that, it is obvious that *A.archangelica* is found of cool climates and growers do not have to fear frost during its vegetative season (Hornok 1992, Bomme 2001). The optimal temperature reaches from 5 to 19°C (Hornok 1992). Lower growing temperature can indirect give a higher yield by decreasing pest development (Charbonneau et al. 1993).

Temperature can also be used to control breakage of dormancy of angelica seeds, where germination can be of a problem. According to Bavarian directives for growing angelica roots, there are different ways to break the dormancy and get a uniform and fast germination. One way is to use heat. The day temperature should be around 30ºC and night temperature at 20ºC. This is achieved by floor heating system with 25ºC combined with transparent plastic film to cover the soil and shading for too strong sun light (Bomme 2001).

Another way is usage of a cold treatment, stratification. This is either done by one to two years cold treatment of dried seed, or when a shorter time is wanted by pre−swelled seeds, giving only one to four weeks of stratification. Seeds are laid on wet filter paper or in a ventilated bath for an hour so the seeds will swell. In the next step the seeds are placed into cold storage where temperature is held at 5−10ºC for one to four weeks, as mentioned earlier. When this has been done, a drying period follows. Seeds are dried with different methods, e.g. with drying cabinet or oven, with hot air treatment (blow−dryer) or spread on absorbent paper. It is important that the seeds are seeded in a near future after this treatment, but the seeds can be stored for some days without serious loss of germination. Same above mentioned treatment can be used, but leaving out drying of the seeds in last part of the treatment. The seeds should not be dried out during the two weeks of stratification (Bomme 2001).

When seeds have germinated the temperature should be held at 16ºC during day and lowered during the night. Temperature also plays a role in post harvest treatment as drying the roots (Bomme 2001).

10.2 Soil/growing media

Because of the shallow (0.4−0.5 m) but wide root system combined with large foliage area, *A.archangelica* needs a good water access during cultivation, otherwise the roots will not develop proper and result in declined yield. This can though be taken care of if cultivating on a sandy soil with appropriate irrigation which corresponds to annual precipitation of 0.6−1.3 mm (Hornok 1992).

Both soil type for field cultivation and substrate type for greenhouse production influence the growth and yield of *A.archangelica* roots. Sandy soil is not recommended for field growing of roots, because the danger of dehydration. During a field trial, the first year production was 50% less (0.9 T/ha) than roots growing in clay loam and organic peat, followed by second year production giving smaller plants compared to plants grown on other soils tested. Even though sand is not recommended to use as a growing media for outdoor production of angelica roots, sand showed to be give a high yield when used in greenhouses, comparing sand with dark peat. Sand has as well an advantage when harvesting the roots, because cleaning of roots becomes exceedingly easier (Charbonneau et al. 1993).

Cleaning roots was found to be a problem in the trial for the roots growing in clay loams (Charbonneau et al. 1993), whilst the roots are spindle−shaped with a lot of rootlets (Grieve 1979), making cleaning difficult.

The best soil of the three tested in field, appeared to be organic soil, but with difficulties concerning cleaning here as well. However, the clay loam could reach the same yield as organic soil when fertilisation was added (Charbonneau et al. 1993). Hornok (1992) advises to use soil originating from swamps, since here gathering of roots are easy and higher yield then mineral soils are expected. He states that it is important to have a soil which is rich in nutrients and humus with a pH between4.5−7.3, whereas Kowalchik & Hylton (1998) reports a more precise pH at 6.3.

Three different growing media, granulated rockwool, dark and light peat moss, was tested and compared in a greenhouse trial. Granulated rockwool was considered to give considerable small yield (2 T/ha) since most of the roots turned out to be rotten. Explanation for the rotten roots was thought to be rockwools ability to keep to much water for angelica roots. Dark peat moss showed to give the highest yield (mean 84.5 g/plant), and with supplemental light during winter, yield could rise. Sand was also tested as a growing media in the greenhouse, and gave, comparing to in the field, positive outcome. Sand yielded even more then dark peat moss, but needed supplements of daily irrigation and fertilisation.

Charbonneau et al. (1993) concludes when having a root production, organic soil should be used if cultivated in field, whereas in greenhouses sand should be adopted to give a high yield but then with daily fertilisation and irrigation.

Preparing soil for direct sowing of *A.archangelica* for field practising is done in August (Hornok 1992) to September (Galambosi 1994), giving a fine structure to soil and a well−compacted seedbed by cultivation, eliminating furrows, weeds and lumps.

Bomme and The Bavarian State Institute for Agriculture (LfL) has been giving out practical guidance and advises since 1984 for German farmers producing angelica root for herbal medicinal purposes. Last publicised folder from 2001 is the 4th edition and is based mainly on their own research in Bavaria.

Bomme (2001) emphasise the need of making a soil analyse before starting to grow any sort of medicinal herb, mainly for the hard legislation and requirements set up by governments. Soil used for angelica production should be free from pollutant of heavy metals (Pb, Cd and

Hg) and not be fertilised with sludge. High quality product will be achieved by profound porous and very fine soil preferably without weed. Stones in the soil can cause problems when harvesting and cleaning the roots and therefore give a poor quality (Bomme 2001).

10.3 Light

Seeds are in need of light to germinate (Ojala 1985, Kowalchik &Hylton 1998). Continuous light with average intensity of 2000 lux gave the highest percent of germinated seeds in a trial conducted by Ojala in 1985. Long−day treatment (16 h of average intensity of 2000 lux) gave a lower result of germination. Ojala (1985) showed that the seeds need light to germinate by total darkness treatment, resulting in no germination what so ever.

During vegetation period partial shade is recommended (Kowalchik &Hylton 1998). Additional light treatment is discussed to give a higher concentration of oil in plant (dry weight), with additional light 4.0 mg/plant and without 2.3 mg/plant dry weight (Letchamo et al. 1995).

10.4 Fertilisation

LfL has been doing research on *A.archangelica* fertilisation requirements (Bomme 2001). Investigation shows that angelica requires very high potassium (K) intake (Dachler & Pelzmann 1999, Bomme 2001) and lack of K is rapidly seen on elderly leaves having yellow stripes and necrotic spots (Bomme 2001). Angelica is as well in need of boron (Dachler & Pelzmann 1999). Nitrogen (N) should be applied in two or three times during the growing period, the first time around end of March, and three weeks before planting of seedlings or three weeks after germination. The second and third applications should be made in late April and in June, respectively. Farmyard manure and liquid manure is not recommended by Bomme (2001) since it can lead to excessive bacterial counts in crops. This is on the other hand recommended by Dachler & Pelzmann (1999) since *A.archangelica* has a high NPK demand, but point that excessive supply of N can lead to a negative development of roots. 50 kg/ha N should be given before the seedling the first year and in the second year another ration of 50 kg/ha N during beginning of vegetative phase. For a good root development the K_2O could be as high as 200 kg/ha, but 120 kg/ha is satisfactory. Recommended P_2O_5 ration is 50−80 kg/ha.

Inorganic fertiliser (mineral fertiliser) should be applied before planting or seeding since it can cause too high salt concentrations in the soil (Bomme 2001).

In field, fertilisation at transplantation gave larger yield on all tested growing substrate (organic soil, clay loam and sand) (Charbonneau et al. 1993).

Recommendations for commercially grown angelica are not targeted to special production parts. Hornok (1992) recommend 60−70 kg/ha of N, 100−200 kg/ha of

P_2O_5 and 150−180 kg/ha K_2O before planting or sowing in August, and then adding 70−80 kg/ha of N top−dressing in early spring (Hornok 1992).

For greenhouse production 7 µmol/l N and 0.8 µmol/l P was found to be sufficient for root growth, but neither N nor P level had significant effect on root yield (Charbonneau et al. 1993).

Producing organic *A.archangelica* derived products, pre−fertilisation with 4−5 kg/m2 compost is claimed to be enough for good yield (Galambosi 1994). It is not told whether these recommendations are for root production or other parts of angelica.

During a part trial in Norway in year 2000−2001, different varieties of *Angelica archangelica* from German, Hungarian, and Norwegian seed companies were tested. In this trial, fertilisation of the field took place before sowing with the following values: 120 kg/ha N, 32 kg/ha P and 96 kg/ha K. These values were also used in the two other trials conducted in the same study (Dragland & Mordal 2002).

Table 3. Application of fertilisation in kg/ha from different trials of Angelica archangelica.

Fertilisation (kg/ha)	N	P2O5	K2O	Mg O	Ca O
Dragland & Mordal 2002	120	32	96	*	*
Bomme 2001 (LfL)	122	72	419	36	186
Charbonneau et al. 1993	50	872	166	*	*
Hornok 1992	60−70	100−120	150−180	*	*
Dachler & Pelzmann 1999	50 + 50	50−80	120−200	*	*

10.5 Water

Additional watering is needed when growing on black plastic during May and June, otherwise flowering will be induced(Galambosi 1994), which can be beneficial when producing seeds, but not wanted when producing roots. Root production in greenhouses is found to have a interaction between substrate and irrigation, angelica grown on dark peat moss yielded 57% more dry root mass (DM) than plants grown on the same media but irrigated when needed. Exception was sand, where there was no difference in yield whether the plants was irrigated when they where dry or every day (Charbonneau et al. 1993).

10.6 Propagation

10.6.1 Vegetative propagation

Little research has been performed on vegetative propagation of *A.archangelica*. In Finland a trial was conduced to produce angelica for coumarin extracts. They succeeded in producing an embryogenic cell line made from callus from angelica seeds (Kummala et al. 1997).

The same department showed some years later a cell line which has retained its embryogenic capacity for five years without decreasing in its quality. This cell line is recommended to be used as an inexpensive way to propagate angelica *in vitro*. Highest coumarin content was produced by a medium containing 3.0% sucrose. Main coumarins found in leaves were isopimpinellin and isoimperatorin. Level of coumarin content was as high as in wild plants. Plantlets were subsequently transplanted direct to a mixture of soil and vermiculite, where 63% grew into full plants in two years. After 56 days the maximum dry weight and coumarin content was achieved. Plants maintained their viability after being exposed to cryopreservation. Production of *in vitro* propagation of angelica is recommended in a two−phase cultivation system, starting with sucrose feeding to obtain large amount of embryogenic material. Next step is a medium change to a lower concentration of sucrose, which will further activate embryos to plantlets (Eeva et al. 2003).

10.6.2 Seed propagation

Propagation with seed is the common way to reproduce angelica (Heeger 1989, Galambosi 1994, Bomme 2001). Thousand−seed weight is variable, ranging from 2.082−8.497 g according to Heeger (1989), with a narrower span of 2.1−5.4 g according to Bomme (1997, 2001).

A.archangelica is not found in retail market, but can be ordered from special firms (Bomme 1997, 2001). Except from the special seed firms, wild angelica seeds are sold. *A.archangelica* is not even mentioned in the German list of varieties of MAP. This has lead to a market where the quality of seeds are not as high as wanted from the growers. German trials have been conduced to reduce the low standard of the seeds and establish a seed market for *A.archangelica* with a good quality. During five years different seeds from different European seed providers were tested. Six German seed providers where selected as having the best seeds, regarding essential oil content in roots, drying ratio, and root development (Bomme 1997).

10.6.3 Sowing and planting

Direct sowing

Direct sowing takes place end of summer (Dachler & Pelzmann 1999) in late August (Bomme 2001) till September (Galambosi 1994). Seeds used for sowing should be harvested in July to overcome dormancy (Bomme 2001). Germination period is four weeks (Heeger 1989, Bomme 2001). During germination it is important to keep the soil moist (Dachler & Pelzmann 1999). Germination rate is about 60% (Heeger 1989).

Ploughing is advised to be 30−35 cm deep (Hornok 1992). Sowing density is 4 kg/ha, 1−2 cm deep with a distance between rows of 50, 62.5 or 75 cm wide. Cluster planting is possible with 5−10 seeds/cluster. After sowing application of a pressure roller to obtain appropriate contact between seed and soil is proposed (Bomme 2001). Hornok (1992) suggest a sowing density of 18−20 kg/ha.

According to Dachler & Pelzmann (1999) sufficient row spacing is 50 cm, planted 0.5−1 cm deep since germination is induced by light. Sowing density is 4 kg/ha, thereby agreeing with Bomme (2001) but is also suggested to reach from 10−15 up to 20 kg/ha. This is corresponding to Heeger (1989), who suggest a sowing density of 20 kg/ha. For seed production for extraction purposes seeds should be sown 100x60 cm to obtain larger amount of oil. Further Heeger (1989) recommend either a 1.5 year or 2 year cultivation for both root and seed production, this to have an adequate development of the plant and by that obtain yield as high as possible.

Plantlets

Ebert (1982) and Heeger (1989) imply a growing of plantlets, and not direct sowing on the field. Sowing density of 3 kg/ha for producing plantlets on the field whereas in greenhouses 2 kg/ha is needed. Planting of plantlets on fields is due in March to April or in August to September. Cultivation should be on ridges (Ebert 1982, Heeger 1989, Hornok 1992) or cultivated on flat soil (62.5x30 cm) (Ebert 1982).

During a trial in Canada, the highest yield was obtained from a planting density of 30x30 cm (111 111 plants/ha), and suggested is that the yield could be increased even more with a higher number of plants/ha (Tremblay et al. 1995). Plantlets should have a height of 10–25 cm when planted on the fields. If plantlets are larger there is a risk of inducing inflorescence, and which leas to a decrease in root yield (Galambosi 1994).

10.7 Pruning

Pruning is said to be necessary only when flower stalks are formed. This is to prevent formation of inflorescences, which will lead to death of the plant. As soon as flower stalks are visual on the field, they should be removed as fast as possible, preferable when they are undeveloped (Dragland 2000). Caution should be taken when pruning or harvesting, since furocoumarins causes serious skin irritations and protection clothes are needed for workers involved in production chain (Heeger 1989, Hornok 1992, Galambosi 1994, Dragland 2000, EMEA 2007).

10.8 Harvest

Both leaves and roots are harvested for further processing. Harvest technologies must be addressed to whether leaves or roots are harvested (Schenk 2008b). There are no machines developed specific for harvesting *A.archangelica* (Galambosi 1994).

A.archangelica can be harvested once or twice per season, depending on what is the main production. Root production is only harvested once and leaf harvesting can be done twice or more (Galambosi 1994).

10.8.1 Leaf harvest

Leaves can be harvested during the whole season, beginning three to four weeks after first leaf is visual until starting to snow (Galambosi 1994) already the first year (Dragland 2000). Leaf part wanted is only the blade of the leaf, whereas leaf stalk is left on remaining plant (Hornok 1992). Only younger leaves are suitable for harvest, since older leaves contain more fibre and are not as tasty (Dragland 2000).

General harvest technologies for leaf differ usually of the size of production. Harvest of smaller field production is done with old traditional tools as reaping hook and scythe and engine–driven machines used in plant nurseries for pruning. Production on a large scale requires more effective methods and technologies, e.g. forage harvester, field chopper, reaper or rotary mower. Fundamental requirement in all technologies above mentioned (both small production or large) is clean cuts free from contamination (Schenk 2008b). Mechanical harvesting techniques have an advantage in this matter, since many of the machines combines collecting harvested material directly without soil contact (Schenk 2008b). Mechanical harvest requires dry leaf material, since wet plant material moulds easier (Galambosi 1994).

Leaf yield

According to Hornok & Gulyás (1992) six kg of fresh leaves are needed to generate one kg of dry drug, giving a drying ratio of 6:1. When harvesting roots there will be residues (leaves and stems etc.) which can correspond to 20–60 t/ha (Bomme 2001). Ebert (1982) gives a more modest yield of 18 t/ha, including stems and petioles.

10.8.2 Root harvest

Roots require a gentile harvest with as little damage on root material as possible. Difficulties concerning root harvest of MAPs are often fragile and have adventitious roots, which can easily get damaged and contaminated with soil during harvest. Usually separation of leaves is done before harvesting (Schenk 2008b). Following German standards when harvesting roots, a maximal of 5% supernal plant material is allowed. Root should be about 50 cm long and adventitious roots about 30 cm long with a thickness of approximately 1 cm (Heeger 1989). Plants that have developed flower stalks and inflorescence are not suitable for root harvest, since root quality will be poor (Dragland 2000).

Harvest time is most suitable during end of September until middle of October (Heeger 1989, Bomme 2001), when the plant has entered dormancy (Heeger 1989), with dry weather (Bomme 2001). At this time, roots contain the highest quality of essential oil but as well the highest root yield. Harvesting roots in March can also be done, but with less yield (Bomme 2001). As with leaf harvest, roots can be harvested the first year, if planted one and one with enough distance in between (Tremblay et al. 1995).

Harvest machines used for potatoes, turnips and sugar beets are not appropriate and effective enough (Galambosi 1994), even though it is suggested in other literature as suitable since its time−saving and get rid of more soil then other harvest methods (saves up to 10% in time) (Bomme 2001). Needed is a machine that removes leaves and stalks, removes soil and lifts the roots (Galambosi 1994). Dachler & Pelzmann (1999) and Bomme (2001) suggest sifting belt harvester and vibratory lifter/harvester. Another method used is to remove supernal plant parts with reaper machine, then machine used for lifting and loosen shrubs is applied for uprooting (Galambosi 1994). Hornok (1992) suggests machinery used for parsley roots. Smaller production can be harvested by hand with fork (Galambosi 1994).

Root yield

A fresh root weighs about 150 to 250 g (Bomme 2001). Yield from angelica roots differ a lot. Galambosi (1994) reports of a difference between 0.6−2 tonne per hectare in the Nordic countries. Dried root yield in Germany is reported to be 2.4 t/ha (Ebert 1982). In another source, yield is 12−22 t/ha of fresh roots, giving 3−6 t/ha dried root (Bomme 2001). Heeger (1989) reports 1.6−2.5 t/ha dried roots, where fresh roots before drying gives 8−10 t/ha. According to Dachler & Pelzmann (1999) root yield can be expected to be 10−13 t/ha of fresh roots, giving 2.5 t/ha of dried roots. Explanation of the differences in yield is considered to be a cause of cultivation methods and cultivation period (Bomme 2001).

To obtain one kg of dry drug from roots requires four kg of fresh roots, giving a drying ratio of 4:1 (Hornok & Gulyás1992). Similar figures are given by Bomme (2001) with drying ratio of 3.5 to 4.3.

Essential oil from angelica root differs as well as the fresh root yield. This has to do with cultivar and provenance, from 0.6 to 1.2 volume percent. A yield of 15 t/ha fresh roots gives 7.5−22.5 l/ha of essential oil, equivalent to 6.6−19.8 kg/ha of essential oils from angelica (Bomme 2001).

10.8.3 Seed harvest

Seed harvest of *A.archangelica* is due only after two or three years (Dragland 2000), being a biennial plant (Grieve 1979). Harvesting of seeds takes place during July and August, when the colour of the seeds are yellow or brown (Galambosi 1994). Umbels are cut off with a harvester and collected (Bomme 2001). Best and largest seeds are given by the main umbels (Galambosi 1994, Dachler & Pelzmann 1999).

Seed yield

Every flower umbel yields about 5 g fruits, giving a yield of 2.0−2.5 t/ha (Bomme 2001). Heeger (1989) report that yield should approximately lie between 0.8−1.5 t/ha, whereas Ebert (1982) reports of a yield of 1,2 t/ha cleaned fruits. Dachler & Pelzmann (1999) report of a little lower numbers, 1.0−1.2 t/ha of seeds.

10.9 Postharvest

Medicinal plants are mainly used preserved (Hornok 1992) and very seldom sold as fresh herbs, partly due to short season (Galambosi 1994). As soon as the plant is harvested, one should take measure as soon as possible to prevent plant material to deteriorate and by that lose wanted active substances (Hornok 1992). Processes during postharvest that are of interest when handling medicinal and spice herbs are, respiration; deteriorate of organs; transpiration; decomposition of green pigments; maturation including seed development and influence on amount of active substances (Schenk2008b). By applying right postharvest treatments to plant material these processes can be reduced (Galambosi 1994).

To be able to preserve plant material for medicinal purpose producers usually operate the first step by themselves. By doing so, a high quality of harvested material can be maintained (Hornok 1992). Preservation methods are approached in two ways, drying for dry drug or extracting of oil for essential oil production (Hornok 1992).

10.9.1 Washing

After leaf and/or root harvesting washing of *A.archangelica* is carried out (Heeger 1989 & Bomme 2001). In Bockau (Germany) during the 1950s, washing was made direct in the brook at the field as seen in fig. 5 (Heeger 1989). Since then, a lot has happened and other methods have been developed.

Figure 5. Washing harvested *A.archangelica* roots in a brook in Bockau (Heeger 1989).

Before washing, the angelica roots are cut into large pieces. This method smoothes the progress of cleaning branched roots from stones and soil. It is important that the pieces remain as large as possible; otherwise cutting can lead to losses of active substances. Washing is made in trommel machines with to 20 revolutions per minute (Bomme 2001).

10.9.2 Drying

The cause of drying plant material is preservation to be able to consume plant material for a longer period of time then the growing season without leading to deterioration. When drying, water content in plant material is decreased and different deterioration processes can be reduced, as e.g. bacterial activity, yeast and enzyme transformations, auto−oxidation, non−enzyme browning and moulding. To retain a high quality of plant product, drying should take place as soon as possible after harvesting. Before drying, plant material should be cleaned, cut up and stripped (when leaves) to allow drying to be as efficient as possible (Hornok & Gulyás 1992).

Drying time depends on four parameters, temperature; air humidity; air speed and the amount of plant material to be dried. Since drying effect is individual for plants it is important to know how long and at which temperature. Different plant parts also differ in drying time, where roots take longer time then leaves and flowers being the most rapid plant part to dry (Galambosi 1994).

Another parameter to considerate is economics. Drying machines can be expensive for a producer with little cultivation area, but economically feasible for a large−scale producer (Hornok & Gulyás 1992).

Seeds of *A.archangelica* are dried on the infructescence in room temperature with good aeration. After sufficient drying, the seeds will easily fall of and can be collected. Duration of seed drying is about a week (Galambosi 1994).

When drying leaves the duration between harvest and drying should be as short as possible, since leaves easily moulds. The temperature should be held low at around 30−40°C (Hornok & Gulyás 1992) to prevent aroma to vanish. Temperature span between 35–40°C kills microorganisms on top of the leaves, and by that purify (to an extent) plant material (Galambosi 1994).

To dry angelica roots, they should be cut into 2−4 pieces (if not done by washing) or slices and dried with an artificial drier (Hornok & Gulyás 1992). Duration of drying is around 3−4 days with a temperature of 35°C (Galambosi 1994). A higher temperature span is recommended in Germany, 40−45°C for 20 to 40 hours. Plant material should not be exposed to higher temperature, since essential oil can disappear. A good air flow is needed to get rid of humid air. German pharmacopoeia (DAB) demands maximum 10% moisture content (Bomme 2001).

10.9.3 Extraction of essential oil

Instead of preserving substances by drying, desired substances can be separated. When drying, the end product is preserved plant material, but with separation methods as distillation and extraction the product comes out in a purified form (Schenk 2008b). All vegetable material of a plant can be used for extraction processes for essential oils (Kolta &Hornok 1992). Amount of essential oil differs within plant part (see table 4). Equipment for extracting plant material is usually expensive and requires large investment costs (Dragland 2000).

Table 4. Content of essential oil (%) in dry matters of different plant parts (Dragland 2000).

Plant part	Essential oil content in dry material (%)
Root	0.5−1.0
Leaf	0.2−0.3
Seed	0.6−1.5

Essential oil production of angelica takes about 8−10 hours with a slow steam speed to have an efficient extraction (Hornok 1992). Langleite (1998) suggest a shorter distillation time, about 3−4.5 hours at a temperature at 105−107°C with steam distillation. Raw angelica root with steam speed of 100−150 kg/h, will have a duration time of 300−500 minutes. Dried angelica root with the same steam speed will take between 300 to 700 minutes (vessel of 4 m^3 volume). Steam distillation is the most common way to extract essential oils from medicinal plants. The method produces the purest form of essential oil (Kolta &Hornok 1992).

Steam distillation is not the only way to extract essential oil. Liquid carbon dioxide extraction (Kerrola & Kallio 1994), Superciritical carbon dioxide extraction (SC−CO_2) ((Kerrola et al. 1994, Doneanu & Anitescu 1998), Solvent extraction (Kerrola et al. 1994) and high vacuum distillation (Greer et al. 2008) have all been used to extract oil from *A.archangelica* in different trials.

High vacuum distillation was used in a trial to produce a superior gin. Vacuum distillation is mainly used in petroleum and perfume industry, where the latter is to receive and preserve high quality volatile aroma chemicals. This was as well the case with producing a superior gin since it reduced the amount of monoterpenes and therefore becoming a better flavour compares to gin distilled with traditional distillation methods using high temperatures (Greer et al. 2008).

SC−CO_2 extraction was found to be superior in a trial conducted by Doneanu & Anitescu (1998) because of the quality of the aroma tended to be higher. Advantages with this method compared to other methods (steam distillation and liquid solvent extraction) were: 1) no thermal degradation of most of the labile compounds; 2) no solvent contamination and undesired compounds; 3) and no production of by−products. An optimum procedure was found to extract angelica oil by having a two−step super fluid extraction process, 1 hour of static period at 12,0 MPa/40°C then 2 hours dynamic period at 12,0 MPa/40°C and 0, 5 kg CO_2 h^{-1}. This is run together with a two−stage separation process 6, 0 MPa/10°C and 3, 0 MPa/0°C (Doneanu & Anitescu 1998).

10.9.4 Packaging

There is not much written about packaging regarding angelica. Dried roots should be packed in airtight sealed containers, to prevent humidity and light to enter and to avoid pests (Dachler & Pelzmann 1999, Bomme 2001). PVC or Polyethylene bags should not have direct contact with the drug, since the essential oil can drift to these synthetic materials. Bags made of paper, jute, or synthetic materials are recommended (Bomme 2001). Roots and fruits are collected into 50 kg bales (Ebert 1982).

10.10 Diseases and pests

10.10.1 Roots

Since roots are the main usage of *A.archangelica* production pests addressed roots are important knowledge. A fungus disease found on roots is *Rhizotonia crocorum* (Pers.) DC. which is seen as a violet spots on the root and can cause complete rotting of the root (Heeger 1989&Bomme 2001). *Rhizotonia* has also been observed on roots by Dachler & Pelzmann (1999) but also *Fusarium*.

Heeger (1989) mentioned that the insect *Yezabura angelicae* Koch., grubs of Cockchafer (Superfamily Scarabaeoidea) and rodents from the subfamily Arvicolinae (Heeger 1989) are feeding on roots (Heeger 1989&Bomme 2001), where *Y.*

angelicae Koch. is the one who is the most common. Field research in Norway mention problems with what they think is brindled ochre (*Dasypolia templi* Thunb.). Some year's whole fields have been devastated because of this ochre. Thus, it is not being mentioned what kind of damages it causes in angelica (Dragland & Mordal 2002), but the Swedish Museum of Natural History state that the larvae lives within the stalk on various umbelliferous plants and pupate inside the roots (Naturhistoriska museet 2009). Another insect feeding as well on plant parts above grounds and on the root is *Hepilaus sp.* (Dragland 2000).

Postharvest diseases on the drug (Radix Angelicae) following pests have been found: *Plodia interpunctella* Hb., *Ephestia elutella* Hb. and *Stegobium paniceum* L. These fungi can also be seen as post harvest diseases (Heeger 1989).

10.10.2 Leaves

Foliage is not the main growing purpose, but cannot be overseen (Bomme 2001). Five different fungus infections have been reported on angelica, which are listed in table 5.

Problems with powdery mildew (*Erysiphe umbrelliferarum* De. By.) can be identified by white powder−like spots on both upper and underside of leaves. Downey mildew (*Plasmopara nivea* (Ung.) Scroet.) has also caused issues when growing angelica (Heeger 1989, Dachler & Pelzmann 1999). Here, the fungus is mostly seen on underside of leaves as bright spots and later on a whitish fungus boarder around infected tissue.

Leaves can be seen with brownish abscond blains or pustules, which are derived of *Puccinia angelicae* Fuckel (Heeger 1989). *Phyllachora angelicae* Fuckel has also been reported to cause problems in production (Heeger 1989, Dachler & Pelzmann 1999).

Insects attacking leaves are mainly *Chlorita flavescens* F., *Eupteryx atropunctata* Goeze, *Philophylla heraclei* L. and *Lygus campestris* L. All of them make visual damage on leaves. *Philophylla heraclei* L. contribute to larval mining, whereas the three other above mentioned are sucking insects, giving rise to white spots. Heeger (1989) also lists *Cnephasia wahlbomiana* L., *Bourtiella sulphurea* Koch. And larvae of the European swallowtail butterfly, *Papilio machaon* L. (Heeger 1989). *P. machaon* is monophagous on *A.archangelica* in southern Sweden (Wiklund & Friberg 2008) and for the wood mouse (*Apodemus sylvaticus* L.) on Iceland angelica is the major autumn and winter food. Wood mice also feed on green parts of angelica during the whole year (Bengtsson & Rundgren 1989).

Other pests that attack angelica are *Tetranychus urticae* Koch. *T. urticae* showing yellow bright spots (Heeger 1989).Bomme (2001) also reports attracts of various spider mites. Ojala (1986a) reports that predation of *A.archangelica* occasionally causes losses in seed yield, population size and structure. Heavy grazing of reindeer (*Rangifer tarandus* L.) was a problem for some of the research fields in Finland (Ojala 1986a). Other ungulate, as cattle, is said to fancy angelica. Rests from root harvest (leaves and stalks) was given to the cattle to feed on (Heeger 1989).

10.10.3 Stalk

Two aphids, *Yezabura angelicae* Koch. and *Aphis fabae* Scop., have been reported to be located on lower and upper part of angelica stalk, respectively (Heeger 1989). Brindle ochre (*Dasypolia templi* Thunb.) larvae which live within the stalk (Naturhistoriska museet 2009) are reported too (Dragland & Mordal 2002).

Flower stalk

Large damages can be made on the flower stalks by *Sclerotinia.* An attack by this fungus causes the whole flower stalk to die from the top down and inside the stalk black fruiting bodies are revealed (Bomme 2001). The black bean aphid *Aphis fabae* Scop. can also cause damages (Heeger 1989).

10.10.4 Fruit and seed

As mentioned above, wood mice (*Apodemus sylvaticus* L.) have angelica as their main autumn and winter food. During autumn and winter they mainly eat the seeds but also other decaying fragments of the plant. If this is a problem in field cultivation was not investigated in the trial, since it was focused on the population of wood mouse and not on angelica (Bengtsson & Rundgren 1989).

Larvae of *Phaulernis fulvigutella* Zell. destroyed 46% and 49% of seed yield in a series of field trials in Finland. In one of the field trials larvae were found in every individual flower (Ojala 1986a). Matured larvae from *Papilio machaon* L.

have been found on half–ripen fruits as well as *Leucanium pulchrum* March., a scale insect.

Heeger (1989) mentioned that large collection of brown lacewings (Hemerobiidae) was found in German trials, but not regarded as a pest, rather a fender, which feed ravenous on all kind of insects (Heeger 1989).

Table 5. Diseases and pests reported on Angelica archangelica L. from collected various sources.

Plant part	Fungus	Pest
Root	*Rhizotonia crocorum* (Pers.) DC. *Hepilaus* sp. *Fusarium*	*Yezabura angelicae* Koch. Grubs from Scarabaeoidea subfamily Arvicolinae (Rodents) *Dasypolia templi* Thunb. *Ephestia elutella* Hb. *Stegobium paniceum* L. *Plodia interpunctella* Hb.
Leaf	*Erysiphe umbrelliferarum* De. By. *Plasmopara nivea* (Ung.) Scroet. *Puccinia engelicae* Fuckel *Phyllachora angelicae* Fuckel	*Lygus campestris* L. *Chlorita flavescens* F. *Eupteryx atropunctata* Goeze. *Philophylla heraclei* L. *Cnephasia wahlbomiana* L. *Bourtiella sulphurea* Koch. *Papilio machaon* L. *Tetranychus urticae* Koch Reindeer Wood mouse (*Apodemus sylvaticus* L.)
Stalk		*Yezabura angelicae* Koch. *Aphis fabae* Scop. *Dasypolia templi* Thunb.
Flower stalk	Sclerotina	*Aphis fabae* Scop.
Fruit		*Leucanium pulchrum* March. *Papilio machaon* L. *Phaulernis fulvigutella* Zell. Wood mouse (Apodemus sylvaticus L.)

10.10.5 Weed

Since there is no specific machine developed for angelica (Bomme 2001), machines for potato production is used for weed control. Old Norwegian weed control was done by cultivation between rows in early spring and covering the soil, which gave time for angelica to establish its large leaves (Dragland 2000). The same strategy is recommended by Galambosi (1994) for organic production. Galambosi got highest yield when using black plastic as covering material, followed by grass. Hornok (1992) suggests chemical weed control.

Couch grass (*Elytrigia repens* L.) is reported to be a problem in Germany (Bomme 2001).

10.10.6 Prevention and control

A preventive measure for a healthy field crop and decrease in pests and diseases is according to Bomme (2001) is to avoid cultivation of young and old plants together. Further suggestions are a good crop rotation. *A.archangelica* should lie fallow for five to six years (Dachler & Pelzmann 1999).

Rapeseed and clover is not recommended as crop rotation, since it can lead to an increase of Sclerotinia, which attacks roots of angelica. Cover crops which need much herbicides are disregarded to. Instead as preceding crop, any root and tuber crop or grains should be planted. Aftergrass should be grains of any kind (Bomme 2001).

Proposal of other measures to prevent pests is to use cover during the early part of the season. Cover the crop in that early stage will lead to decrease or even preventing of attacks from Dasypolia templi larvae, since females cannot lay their eggs on the plant (Dragland & Mordal 2002).

Another way to decrease the number of infected plants is to use temperature. Methods using temperature can mainly be used in greenhouse production, where temperature can be affected. Charbonneau et al. (1993) used this to reduce attacks of Dasypolia templi. Day temperature was lowered from 21°C to 16°C (Charbonneau et al. 1993).

Treatments of different fungus control against e.g. powdery mildew starts in May. Against aphids different pesticides can be used (Hornok 1992). Since angelica is a plant used for both food and medicinal purpose, caution of legislation should be taken when using pesticides and fungicides (Bomme 2001). Specialised pesticides are listed in Hornok (1992), but in online database of the Federal Office of Consumer Protection and Food Safety (Bundesamt für Verbraucherschutz und Lebensmittelsicherheit: BVL) there are no records of recommended or forbidden pesticides (BVL 2009).

11 Discussion

There is great need of more research on this plant, since different literature gives different information. 1000−seed weight differs very much, which should lead to problems when sowing or calculating how much needed for cultivation. Fertilisation, both for greenhouse and field production differ as well. Greenhouse production is a matter where very little research has been done. Regarding pH, which in some literature have a span of 4.5 to 7.3 (Hornok 1992) and more precise in other, 6.3 (Kowalchik & Hylton 1998), there should be more research done. Optimum temperature for *A.archangelica* differs from 5−19 °C (Hornok 1992) should also be given more attention as in more research. Knowledge about usage of pesticide on angelica seems to be none, except from Hornok from 1992 (UK), which is 17 years ago. Surely there have been changes concerning this too, and new legislations from EU. Problems of not having any seeds on the market, and can only be found in very small specialised seed firm (Bomme 1997, Bomme 2001) could be a decline in seed quality. This seems to be a problem in Germany (Bomme 1997).

There is though an interest of this plant. Research is currently being done in Sweden at the Nordic Genetic Resource Center. Two projects are running, one testing the germination ratio of seeds and the other concerning genetic diversity of different *A.archangelica* populations in Greenland, Iceland, Norway and Finland (Göransson 2009).

There are other countries also doing research. Germany has a long tradition of producing MAPs, and this can also be seen in their detailed books and research. I strongly recommend these books to get further knowledge of how to produce high yielding *Angelica archangelica*. It is sad though, that these books have fallen into oblivion and is often no longer available in Nordic libraries, and if they are, they are old and not the latest edition. This is probably due to the language barrier, but hopefully the books can be translated and therefore be open to a broader public.

The purpose of this literature study was gathering of information about this plant, and to evaluate if it is possible to reintroduce this plant to Scandinavians and get a Nordic production. Angelica has been used as a medicinal and vegetable plant in Scandinavia (Fjellström 1964). Perhaps in some years we could have locally produced *A.archangelica* in supermarkets, sold as a vegetable delicacy. Since the plant is relatively easy to grow, and the season starts early, the yield from the leaves and stems could be harvested as early as April until late September, depending on climate. There would though be a risk of selling it as a vegetable in supermarkets, since it is phototoxic and can cause skin damages when exposed to sun (Duke 1987, EMEA 2007). I have not found any angelica producers in Sweden or other Scandinavian countries, except on Iceland. There have not been any reasons stated of why Scandinavian has no cultivation and production of *A.archangelica*. Since there have been problems in finding sources describing the market for *A.archangelica*, no information about price is published in this literature study. There is though one source reporting from 1978 in Germany, where angelica archangelica had a value of 92 000 Euro (Ebert, 1982). Therefore it is hard to calculate the today value of the plant, and by that calculate if it has some economical value in a potential Scandinavian production. Perhaps comparing with other MAPs cultivated for its root, as parsley, could give a proximate value.

Successful trails in Finland where *in vitro* propagation of *A.archangelica* from seeds is providing future agricultural businesses a cheaper and faster way to produce plantlets for field cultivation (Eeva et al. 2007).

Harvesting roots efficient can be a problem, since there is no machine specialised in *A.archangelica* (Galambosi 1994). Hornok (1992) suggests machinery used for parsley roots, probably because parsley have similarities in root structure.

Wood mouse is mentioned as a pest on angelica, but is not clear whether it makes a lot of damage in cultivations. Problem could be when direct sowing in fields, since they usually feed on the seeds during the winter (Bengtsson & Rundgren 1989). In south of Sweden, there could possibly also be a problem with the monophagous larvae of *Papilio machaon* (Wiklund & Friberg 2008).

Advantages of having a European production of MAPs are many (Bomme 2009). 1) A possibility to get a higher quality standard during cultivation and during the whole production chain; 2) easier to have a higher hygiene standard; 3) European laws are much harder concerning phytopharmaceuticals, drugs and food legislation; 4) documentation of the process; 5) traceability; 6) locally produced products; and 7) an alternative earning for agricultural businesses. There is also a high potential of producing domestic MAPs. More people desire locally produced MAPs and request also MAPs with a higher quality regarding e.g. constituents, contamination, and pesticides. Of course there are many disadvantages as e.g., higher costs for labour, climate conditions and lack of knowledge about domestic cultivation. Bomme (2009) also imply that there is little specialised technical literature available concerning different MAPs.

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Figures

Figure 1. Forsnäs Hemman och Malgomajuddens gård. 2009a. Collected from: http://www.acc.umu.se/~yisca/Kvanne/vilda%20vaxter%20som%20mat%20och%20medicin2_midi.jpg (2009−11−11).

Figure 2. Köhler, F.E. 1887. *Angelica archangelica* L. In: Köhler's Medizinal-Pflanzen in naturgetreuen Abbildungen mit kurz erläuterndem Texte. Atlas zur Pharmacopoea germanica, austriaca, belgica, danica, helvetica, hungarica, rossica, suecica, Neerlandica, British pharmacopoeia, zum

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Figure 3 (a). Hultén, E. 1950. Atlas över växternas utbredning i norden: Fanerogamer och ormbunksväxter. Generalstabens litografiska anstalts förlag, Stockholm, Sweden. Picture number 1344 on page 345. Collected from: http://linnaeus.nrm.se/flora/di/apia/angel/angearcs.jpg (2009−07−01).

Figure 3(b). Hultén, E. 1950. Atlas över växternas utbredning i norden: Fanerogamer och ormbunksväxter. Generalstabens litografiska anstalts förlag, Stockholm, Sweden. Picture number 1345 on page 345. Collected from: http://linnaeus.nrm.se/flora/di/apia/angel/angearcs.jpg (2009−07−01).

Figure 4. Forsnäs Hemman och Malgomajuddens gård. 2009b.Collected from:
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Figure 5. Heeger, E.F. 1989. Angelica archangelica L., Angelika, Garten−Engelwurz, Engelwurz. In: *Handbuch des Arznei− und Gewürzpflanzenbaues. Drogengewinnung.* Deutscher Bauernverlag, Berlin, Germany. p.246.