Sveriges lantbruksuniversitet
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Swedish ginseng
– possibilities and challenges

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Degree project in Biology
Agriculture Programme – Soil and Plant Sciences

Examensarbeten, Institutionen för mark och miljö, SLU
2014:13

Uppsala 2014

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EX0591, Independent project/degree project in Biology, 30 credits, Basic level, G2E
Agriculture Programme – Soil and Plant Sciences 270 credits (Agronomprogrammet – inriktning mark/växt 270 hp)

Series title: Examensarbeten, Institutionen för mark och miljö, SLU
2014:13

Uppsala 2014

Keywords: Panax quinquefolium, Sweden, ginseng

Online publication: http://stud.epsilon.slu.se

Cover: photo by Martin Jensen, Aarhus Universitet

Abstract

Ginseng is a shade plant with a cultivation period of at least four years. The ginseng root has been used in Asia for thousands of years to strengthen and vitalize the body. This literature review investigated the possibilities of commercial ginseng cultivation in Sweden. Three main areas of challenge were studied, climate, disease and market, based on the growth requirements and production methods of the variety *Panax quinquefolium*. The climate conditions in Sweden seem to be suitable for cultivation of *Panax quinquefolium*. Problems with common fungal diseases of ginseng can be assumed to be small at first, but increase over time. There are three production systems; forest-grown, field-grown under artificial shade and wild-simulated. Field-grown ginseng can be sold to the European or Asian market, but the value of wild-simulated and forest-grown ginseng is only appreciated on the Asian market. To access the Asian market, Swedish ginseng production must exceed a certain amount (~5000 kg dried root). The conclusion is that ginseng can be grown commercially in Sweden, although posing substantial cultivation challenges and Swedish ginseng farmers would have to create a marketing plan and cope with radically fluctuating world market prices.

Keywords: *Panax quinquefolium*, Sweden, ginseng

Sammanfattning

Ginseng är en skuggväxt med en växtperiod på minst fyra år. Ginseng har använts i Asien under årtusenden för att stärka och vitalisera kroppen. Denna litteraturstudie undersökte möjligheterna för kommersiell ginseng odling i Sverige. Tre problemområden studerades; klimat, sjukdomar och marknad, baserat på växtbehov och produktionsmetoder för arten *Panax quinquefolium*. Klimatet i Sverige förefaller lämpligt för odling av *Panax quinquefolium*. Problem med svampsjukdomar förväntas att först vara små för att öka med odlingsareal och tid. Det finns tre produktionssystem, skogsodling, fältodling (odling under artificiell skugga), och vild simulerad odling. Fältodlad ginseng kan säljas till den europeiska och den asiatiska marknaden, medan mervärdet för vild simulerad och skogsodlad ginseng endast kan fås på den asiatiska marknaden. För att få tillgång till den asiatiska marknaden krävs en tillräckligt stor svensk produktion (˜ 5000 kg torkad rot). Slutsatsen är att ginseng kan odlas kommersiellt i Sverige. Ginseng är dock en svår gröda att odla och svenska ginseng producenter skulle dessutom behöva planera för avsättningsmöjligheter och hantera kraftigt fluktuerande världsmarknadspriser.

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1. Introduction

1.1 Background

Ginseng has traditionally been used as an herbal medicine for thousands of years in Asia, where it is used for strengthening and vitalizing the body. There is increased interest in the use of ginseng in Western Europe, where the market for food supplies and herbal medicines is growing. Ginseng farms have now been established in Denmark and Germany and it is of interest to know whether ginseng can be grown commercially in Sweden.

Ginseng is a perennial plant that grows on the floor of hardwood forests. It is grown for its valuable root, which contains stimulating and vitalizing agents. The ginseng seed requires a cold and a warm period in order to germinate. The climate in Sweden, with winter and summer temperature changes, could be suitable for ginseng cultivation. Ginseng is not an easy plant to grow and cultivation is associated with many challenges, one of which is the need for shade, as ginseng has to be grown in forest or under artificial shade. Another challenge to ginseng farming is the range of fungal pathogens that attack this plant, which pose one of the main challenges to ginseng growing (Punja, 2011). The disease problem is partly due to the long growing period of at least four years (or often more, depending on cultivation choices), during which the pressure of fungal pathogens increases. This also results in another problem, namely that it is not possible to grow ginseng in the same location twice, or at least not for a very long time.

The cost aspect of ginseng farming is also important. It is of interest to investigate the financial incentive for ginseng farming, for example the possibilities to access different markets such as the Swedish/European market, the Asian market or niche markets. One niche market could be organic farming, with a possible higher trade-off value.

1.2 Objective and methods

The objective of this study was to investigate the possibilities for growing ginseng commercially in Sweden. First, background information is provided, with a description of the plant, its growth requirements and different production methods. The three main areas of challenge for growing ginseng in Sweden, climate, disease and the market, are then investigated in three separate sections. In the climate section, climate conditions in Sweden are compared against those required by ginseng. The disease section describes the fungal problem and the market section evaluates the possibility of profitable economic production in Sweden. Lastly, the possibilities for Swedish ginseng farming are discussed and conclusions are drawn.

Information for this study was gathered mainly through a review of the literature. Additional information was obtained from ginseng growers, researchers and different agencies and through a field trip to a large-scale, artificial shade ginseng farm in Germany.

2. The ginseng plant

2.1. Species

Ginseng is a member of the Araliacaea family, which includes about 700 plant species. Carrot, celery and parsnip are also members. The 700 species are divided into 70 genera, one of which is *Panax*. There are 5-13 species of the *Panax* genus (Persons and Davis, 2007), but nomenclature has only been agreed for five of these (Table 1).

Table 1. Currently identified species within the *Panax* genus and their origin

Latin name	Common name	Native to
Panax ginseng	Asian or Korean ginseng	Siberia, Korea, China
Panax japonicum	Japanese ginseng	Japan
Panax notoginseng		China
Panax trifolium	Dwarf ginseng, ground nut	North America
Panax quinquefolium	American ginseng	North America, Canada

Although all *Panax* species have medicinal properties, they differ in chemical composition and concentration and are used differently in Chinese medicine (Pritts, 1995). *Panax ginseng* and *Panax quinquefolium* are regarded as having the greatest health benefits and are the most expensive products. These two species are quite alike and probably originated from the same plant a long time ago (Persons and Davis, 2007).

Panax ginseng was discovered at least 5000 years ago in Manchuria, China. Due to great demand, wild-growing ginseng is now almost extinct in Asia (Persons, 1994). Wild Korean ginseng and the cultivated ginseng plant (*Panax ginseng*) are botanically identical. They are also identical to the ginseng plants native to Manchuria and Siberia (Persons, 1994), where *Panax ginseng* grows wild. There is an herb called 'Siberian ginseng' but this is not ginseng at all, although it is from the Araliacaea family (Persons, 1994). Korea started cultivating ginseng in the 16th Century, started producing a surplus in the 20th Century and began exporting, and is now the major producer of *Panax ginseng.* The ginseng produced in Korea is exported to China, Japan and other countries in South East Asia (Persons, 1994).

Panax japonicum has grown wild in the mountains of Japan since ancient times. It differs botanically from *Panax ginseng* and is not as valuable. The Japanese also cultivate *Panax ginseng* and export it to China and Hong Kong (Persons, 1994)**.**

Panax notoginseng has pharmacological qualities that resemble those of the two most valued species (*P.quinquefolium* and *P.ginseng*) and it is becoming increasingly popular as a medicinal herb.

*Panax trifolium***,** also called dwarf ginseng or ground nut, is found in America. It is not used for medicinal purposes (Persons and Davis, 2007).

Panax quinquefolium, also called American ginseng**,** was discovered in Montreal in 1716 by a Jesuit priest who had heard about this plant in China (Persons, 1994). Harvesting this wild ginseng and exporting it to China became a lucrative business in the USA and resulted in this wild ginseng species becoming scarce by the end of the 19th Century (Pritts, 1995). Work to grow ginseng then began but the first attempts often failed and it was believed that ginseng could not be cultivated (Persons,

1994). In the early 1900s many ginseng plantations were wiped out by alternaria blight, a foliar disease, and ginseng production stopped until a cure was found by using copper sulphate for fungal suppression (Pritts, 1995). The intense harvesting of wild ginseng is a threat to its continued existence and the species has been listed by the Convention on International Trade in Endangered Species of wild fauna and flora (CITES) (Persons, 1994). Since it is difficult to distinguish between wild and cultivated ginseng, the same regulations apply for both (Pritts, 1995). This would affect Swedish imports of root or seedlings, since growers would need import and export permits (see section 4.8).

The commercial production of ginseng involves the two species *P. ginseng* and *P. quinquefolium*. This study mainly focuses on *P. quinquefolium*, but differences between the varieties are discussed in section 5.9.

2.2 Plant physiology - *Panax quinquefolium*

Panax quinquefolium is a perennial plant, about 50 cm high, which grows naturally on the forest floor. *Panax quinquefolium* is highly self-fertile (Schluter and Punja, 2000), but bees and flies can provide some cross-pollination (Pritts, 1995). In America, the seeds are planted in the autumn, during September, October and early November. They can be planted until the ground is frozen. It is also possible to sow seeds in the spring, but only in a narrow window of time and only in regions where the ground thaws early so the seed has not already germinated (Persons and Davis, 2007).

The seed undergoes deep combined dormancy and will not grow until 18-20 months after harvest. There is physical dormancy, in that the embryo is not fully developed, and this is broken naturally during the following summer, triggered by heat. The second part of the dormancy is broken by a cold period that occurs naturally during the following winter (Jensen, 2001). This is described further in section 4.9. When the seed finally germinates, a small root develops and a stem with three leaflets is produced. Every year, a bud containing the next year's foliar tops develops on the root. The plant also produces a new prong every year. A prong is a compound leaf, consisting of five leaflets, which is the reason for the species name '*quinquefolium*' (Jensen, 2001). The plant usually blossoms when it is at least three years old and it carries between 2-50 berries, which mature from green to red. In Denmark, blossoming occurs in June-July, and lasts for about four weeks (Jensen, 2001). Each berry contains 1-3 seeds and in America these fall to the ground in August or September (Persons, 1994). By the third year, the plant can have three prongs if it is field-grown, while native wild plants can take 10 years to become mature, i.e. become three-prongers. A ginseng plant growing in the wild can reach over 100 years old (Pritts, 1995).

The root is long and slender at first, but eventually grows into the shape of a man (Persons, 1994). The root weight after the first growing season is normally below 1 g and the average root weight after 4 years is about 14 g (Oliver, 1998). The root pushes downwards to counter the upward growth of the rhizomes and in this way does not grow above the soil surface (Jensen, 2001). During the first years the root grows rapidly, doubling or tripling in size, but eventually growth slows down to a 20% increase in root weight per year. A scar is formed when the foliage stem breaks off each year and the age of the root can be calculated by counting these scars (Persons, 1994).

2.3 Native growth range

Panax quinquefolium grows naturally in hardwood forests in the eastern part of North America (Pritts, 1995). It is also indigenous to southern Canada and the south-western USA (Figure 1). Due to

the requirement of the ginseng seeds for a cold period to break dormancy, there is a southern limit to the natural growth habitat of ginseng (Persons, 1994).

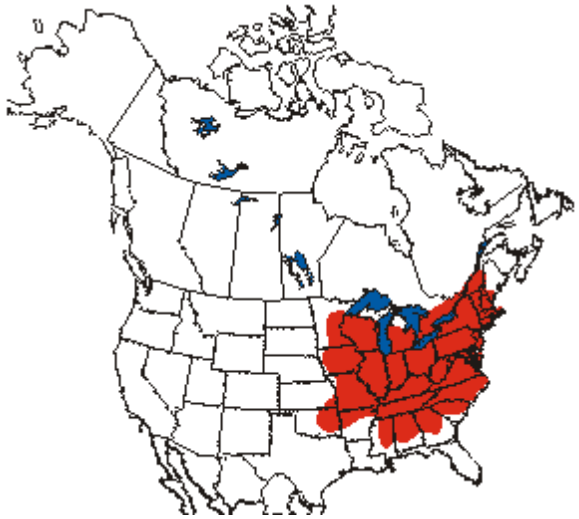

Figure 1. Map showing the range of wild ginseng (*Panax quinquefolium*) in America. Image courtesy of the Royal Ontario Museum, 1982-1987.

Panax quinquefolium is cultivated commercially in Wisconsin, Michigan, North Carolina, Ohio, Tennessee and a number of other states in the USA. In Canada, the major cultivation regions are Ontario and British Columbia (Punja, 2011). Ginseng is also grown in many locations outside its natural habitat, western North America, China, Canada, Australia and New Zealand being examples. In addition, some countries in Europe are trying ginseng farming on a small scale, for example the United Kingdom, Denmark, Germany, France, the Netherlands and Poland (Persons and Davis, 2007; Barbara and Janusz, 2008).

2.4 Medical properties

The two main ginseng species (*P. quinquefolium* and *P. ginseng*) are chemically different and they are believed by the Chinese to have different qualities (Pritts, 1995). The health benefits of *P. quinquefolium* depend mainly on its content of two types of active substances: Polyacetylenes which have been found by Danish researchers to be cancer-inhibiting (Christensen *et al*., 2000), and ginsenosides, which provide many different effects.

The polyacetylenes are sensitive to heat and light and the roots therefore need to be handled carefully (Christensen *et al*., 2000). The gInsenosides, also called saponins, are one of the most important active substances in ginseng. Ginsenosides appear to have different effects, for example, maintaining blood sugar or regulating hormone levels (Persons, 1994). There are 12 different ginsenosides and they are found in both root and top, but normally only the root is used for herbal medicine. Four to six of these ginsenosides make up most of the content (Jensen, 2001). Other effects of ginsenosides include stress reduction, resistance to diseases and increased physical and psychological performance (Jensen, 2001). Although the groups of active ingredients in *P. quinquefolium* and *P. ginseng* are the same (ginsenosides and polyacetylenes), there are differences

in the types of ginsenosides present (Punja, 2011). In *P. quinquefolium* the ginsenosides seem to have a calming effect, whereas in *P. ginseng* the ginsenosides are considered more as stimulants. Two of the main groups of ginsenosides are Rg and Rb and, according to Snow & Snow (2009), "ginsenosides with Rg designation are considered stimulants and are found primarily in Asian ginseng. Ginseng found in America tends to have an Rb rating signifying that the root is a relaxant, which provides a calming effect". The most important ginsenosides are considered to be Rb1, Rb2, Rc, Rd, Re and Rg (Christensen *et al*., 2000).

2.5 Ginsenoside levels in plants

The ginsenoside levels in *P. quinquefolium* vary with age, plant part, soil nutrient status and population (Table 2).

Table 2. Factors affecting ginsenoside levels in American ginseng (*Panax quinquefolium*)

Factor	Effect on ginsenoside levels
Age	Levels increase with age until about 5 years old and then stabilize
Part of plant	Levels highest in leaves and root hair, followed by root and stem
Nutrient status	Levels and composition are influenced by growing conditions
Population (genotype)	Levels and composition of ginsenosides vary between ginseng populations

Ginsenoside levels vary in different parts of the plant. They are highest in leaves and root hairs, followed by root and stem (Qu et al., 2009). The leaves are not used because of the standard use of pesticides and because the leaves are wilted at the time of root harvest (Christensen *et al*., 2000). The ginsenoside levels also depend on the age of the root, as the total ginsenoside content is about 3% in one-year-old roots and 8% in four-year-old roots. Plants younger than four years are considered unsuitable for harvest due to their low content of ginsenosides (Court *et al*., 1996). The ginsenoside levels increase until the root is about 5 years old, after which they stabilize. Other factors influencing ginsenoside levels are growing conditions, such as soil nutrient status. For example, nitrogen can have a negative correlation with one ginsenoside and a positive correlation with another (Li *et al*., 1996). A factor that does not alter ginsenoside levels, however, is root size. According to Christensen and Jensen (2009, 2006), there is no significant variation in total content of bioactive compounds with root size. Furthermore, ginsenoside content and composition vary significantly between populations. The variations are quite large and it is suggested that ginseng supplements be labelled with total ginsenoside content and ginsenoside profile for correct usage (Schlag and McIntosh, 2006). Research is underway to genetically improve *P. quinquefolium* and according to Punja (2011), the species has sufficient genetic variation for this to be successful. Such work could provide a more uniform end product with consistent levels of the active metabolites.

A study conducted in Canada examined the hypothesis that mild stress would increase production of active ingredients. Mild stress, such as lack of nutrients, light and low pH, was applied to medicinal understory herbaceous plants. Four plants used for their active ingredients were studied, for example wild ginger and blue cohosh. However, the study found that stress did not increase production of active ingredients but rather that factors which promoted plant growth in general also promoted active ingredient production (Naud *et al*., 2010).

3. Growth requirements for ginseng

The basic growth requirements for *Panax quinquefolium* in terms of site conditions, climate and management have been determined by research and experience in the USA (Table 3). Location, soil conditions, sowing depth, irrigation and fertilization are described in sections 3.1-3.5. The need for shade is described in section 5.6.

Table 3. Growth requirements for *Panax quinquefolium*

Factor	Requirement for ginseng
Location	Well drained, preferably on a slope facing north or east
Shade	78% shade is optimal for American conditions (see section 5.6)
Soil conditions	Organic matter, 4%. pH between 5 and 6.7, calcium content 3360 kg/ha.
Sowing depth	0.5 cm to 3 cm (depending on source)
Rainfall	At least 500 mm per year
Fertilizer	Generally not needed, but possible.

3.1 Location and soil

The location of ginseng production is important and low-lying, wet areas should be avoided, since ginseng is sensitive to water. Drainage is crucial, and the best location is on a slope (>5^{o}) facing north or east to avoid the growing site becoming too warm and dry (Persons, 1994).

Ginseng can be grown in different types of soil, the important factor being that it is well drained (Persons, 1994), although modest water-holding capacity is needed in the top 20-30 cm. Heavy clay or very sandy soils are not suitable for ginseng cultivation, although a dry soil can be enhanced by adding compost. The suggested ideal soil has been described as light-textured loam (Pritts, 1995) and sandy clay (Madsen *et al*., 2001).

Ginseng grows well in soils with a high content of organic matter (Persons and Davis, 2007). In the forest, this is provided naturally with leaves, bark, plant residues *etc*. The content of organic matter in the upper layer should be about 4% for optimal growing conditions (Pritts, 1995). For more information about how to add organic matter, see section 4.5.

Pritts (1995) identified pH as the single most important soil characteristic, affecting the size, weight and shape of the root. According to Persons (1994), some regular soil testing is a good idea, since the chemistry of the soil probably changes with time and some mulch can lower the pH quickly (leaf and bark compost has a slightly acidifying effect). Pritts (1995) recommends a pH between 5.6 and 5.8, while Persons (1994, 2007) recommends a pH level between 5 and 6.7. A study of wild-growing ginseng showed a mean pH of 5 in soils hosting wild populations (Beyfuss, 2000 *cit*. Persons and Davis, 2007).

According to a previous study on the natural growing situations of wild ginseng, the sites lie on calcium-rich soils with a mean calcium (Ca) content of 4500 kg/ha (Beyfuss, 2000 *cit*. Persons and Davis, 2007). In commercial growing, a calcium level of 3360 kg/ha is recommended (Beyfuss, 2000 *cit*. Persons and Davis, 2007). Another characteristic shared by the soils in that study was that they had low pH. If the intended site for ginseng cultivation is calcium-deficient, the calcium level can be raised, *e.g*. by adding lime ($CaCO_3$) and gypsum ($CaSO_4$). Since lime raises soil pH, Persons (2007)

suggests adding gypsum, which supplies calcium without increasing pH. A study on acid maple forest soils indicated that adding lime improved growth and survival rate, an effect attributed (at least partly) to the increased level of calcium in the soil (Nadeau *et al*., 2003a). That study also showed that once the calcium requirement was met, addition of organic fertilizer was beneficial (Nadeau *et al*., 2003a). Other effects of calcium are that it can play a role in limiting injuries due to freezing stress (Palta, 1996) and that calcium deficiency can lead to root rot (Stoltz, 1982).

Low pH is strongly associated with high concentrations of aluminium (Al) in the soil (Persons and Davis, 2007) and aluminium is a limiting factor for plant growth and crop production in strongly acidic soils (Foy, 1992 *cit*. Nadeau *et al*., 2003). Calcium alleviates aluminium toxicity (Brunet, 1994). In a study where lime was applied to very acidic soils, calcium reduced extractable aluminium content significantly (Nadeau *et al*., 2003a), suggesting that the calcium-rich soils preferred by ginseng prevent aluminium toxicity.

3.3 Sowing depth

Sowing depth is important in providing the best growing conditions. Sowing the seed too deep makes it difficult for the seedlings to compete with weeds in the spring and also makes them more susceptible to pathogens (Decker, 1946 *cit*. Proctor, 2013). For example, there is a relationship between depth and damping-off disease of ginseng (Yu Yh *et al*., 1990 *cit*. Proctor, 2013). Sowing the seed at too shallow depth, on the other hand, increases the risk of 'spider root', with the roots developing horizontally (Ontario Ministry of Agriculture, 2009 *cit*. Proctor, 2013) and having a low value (Roy *et al*., 2003). There are different opinions concerning the best sowing depth. According to a study of ginseng cultivation with and without mulch (Proctor, 2013), the optimum sowing depth is about 3 cm for maximum root yield and adding mulch has little effect on seedling emergence at different sowing depths. A wider planting depth range has been suggested by Pritts (1995), who recommends not less than 1 cm and not exceeding 2.5 cm. Persons (2007) recommends 1.9 cm sowing depth, but suggests that anything below the surface and down to 2.5 cm will work. Danish research has shown that a sowing depth of 0. 5 or 1.5 cm will double seed germination compared with a sowing depth of 2.5 cm (Madsen *et al*., 2001).

3.4 Irrigation

Ginseng requires at least 500 mm of rainfall each year. If soil moisture is low, ginseng will grow more slowly and produce less seed (Persons, 1994; Pritts, 1995). Ginseng normally does not require irrigation, but it might be needed in extreme drought. According to a Korean study, a soil saturation rate of 65% is optimal (Persons, 1994). Polish research has shown that subsoil irrigation increases root weight (Barbara and Janusz, 2008).

3.5 Fertilization

A moderately fertile soil is sufficient, since ginseng does not require high soil fertility. In forest, as the leaf litter of the forest floor decomposes, micronutrients are released to the roots. Whether and how fertilization is chosen is to some extent dependent on choice of cultivation method (see section 4.5). Fertilization has its pros and cons. For example, it seems to increase the risk of diseases and it affects the appearance of the root, giving it a 'driven' look (see section 4), which is of less commercial interest (lower value) for the Asian market (Persons and Davis, 2007). However, Pritts (1995) suggests some fertilization can be beneficial, and Persons (2007) mentions that if the soil is not rich and fertile, it can be useful to add some fertilizer which is low in nitrogen.

Ginseng grows naturally in forest soils, which are low in nitrogen (organically bound), so nitrogen is normally not applied (Persons, 1994). Although nitrogen increases root mass (Stoltz, 1982), it also has a series of negative impacts regarding diseases, root quality, germination and plant emergence (Nadeau *et al*., 2003b).

Fertilization with phosphorus (P) improves root quality and increases the plant population (Barbara and Janusz, 2008). It also enhances seed production and is beneficial for the root. Phosphorus tends to stay where it is put and needs to be applied at the right depth, 15-20 cm (Pritts, 1995). Potassium (K) can be also used, as it is good for overall strength and disease resistance. It can be found in lime and bone meal (Pritts, 1995).

4. Methods of cultivation

Three distinct methods of cultivating ginseng commercially are used in America (Table 4). The seeds can be spread on the forest floor (wild-cultivated ginseng), planted in beds in the forest (forest-grown ginseng), or sown in fields under artificially constructed shade (field-grown ginseng) (Persons, 1994).

Table 4. Different strategies used for commercial cultivation of American ginseng (*Panax quinquefolium*) in the USA

Method	Positive	Negative
Wild-simulated	Low risk, less work, high value root	Low harvest, long production time
Forest-grown	Less work, less risk, high value root	Low harvest, long production time
Field-grown	High potential profit	High investment, greater disease risk

All three methods have their pros and cons. Small-scale growers are more likely to choose to produce forest-grown ginseng because it is less work, less risk and produces a higher value root. The downside with forest growing is that the yield is significantly lower. Producers of field-grown ginseng under artificial shade, on the other hand, face much larger upfront investment costs (building shade structures, weeding) and a greater risk of diseases, but the potential profits can be high (Pritts, 1995).

Much of the ginseng grown in the USA is sold to the Asian market. When selling to this market, the value of the different roots is an important aspect when choosing production method. Asian consumers value wild ginseng over its cultivated counterpart because it resembles wild oriental ginseng (Persons, 1994). Wild-simulated production is most likely to produce the desired wild-looking roots. Forest-grown ginseng can have either wild- or cultivated-looking roots, depending on the growing conditions. Another aspect to consider is a problem that ginseng grown under artificial shade cannot be grown again in the same spot for a very long time. The soil pathogens build up to a high level during the life of the ginseng crop and new plants cannot survive it. Forest-grown ginseng can be reseeded after a couple of years and wild-simulated plantations do not seem to have this problem of pathogen build-up (Pritts, 1995). Furthermore, all three cultivation systems can be managed organically, although it is much easier to avoid the use of pesticides in a forest-grown or wild-simulated system. In Sweden, there is an organic certification fee of 3500 SEK/year (growing area up to 20 ha) (SMAK, 2014).

For all production methods, good planning is very helpful. Many growers start planning and working their beds 1 to 1.5 years before planting by carrying out soil tests and making adjustments to obtain

the best growing conditions. The intended area is normally tilled several times to get rid of weeds and work the soil (Pritts, 1995).

4.1 Wild-simulated cultivation

This method is closest to wild-growing ginseng and is the easiest and cheapest commercial cultivation method, according to Persons (1994). In the USA, the strategy is to look for plants that normally accompany ginseng, in order to find the best location (Persons and Davis, 2007). Soil testing has to be carried out, mainly to determine the level of calcium and pH, two very important factors (see section 3.1). The soil should be rich in calcium but at the same time acidic, a combination that may not be so easy to find. In a previous study, this combination is referred to as an abnormality and a possible reason for the scarcity of healthy wild ginseng populations in America (Beyfuss, 2000 *cit*. Persons and Davis, 2007). The same study showed that ginseng in the USA mainly grows under sugar maple (*Acer saccarum*) and that sugar maple stores calcium (about 1.8 %) in its leaves which it does not retract before leaf fall. Consequently, the leaf litter where ginseng grows naturally contains a high level of calcium (Beyfuss 2000 *cit*. Persons and Davis, 2007). Sugar maple is not native to Sweden, but can be grown in the south of Sweden.

The first action before planting is to clear the site area. The amount of vegetation that should be removed depends on the intended sowing density. Less disturbance lowers the risk of diseases and a low sowing density also reduces the risk of disease, with a density of less than 3.5 g seeds per m^2 creating a good chance of disease avoidance (Persons, 1994). A higher sowing rate reduces ventilation and increases humidity, making the crop more susceptible to fungal diseases, while the smaller distance between the plants allows diseases to spread more easily. Diseases can spread through the soil, root to root, over the surface, stem to stem, or through foliage. High planting density can also create stress for the plants, by having to compete for water, sun *etc*., which can make them more susceptible to disease (Persons, 1994) (for more about diseases see Chapter 6).

There are many ways of sowing wild-simulated ginseng. One common method is to rake the leaf litter aside, rake the soil (2-3 cm deep), broadcast the seeds by hand and return the leaf litter. More information on sowing wild-simulated ginseng can be found in Persons & Davis (2007).

4.1.1 Cost of cultivating wild-simulated ginseng

The suggested budget shown in Table 5 is based on a previous budget prepared by Persons and Davis (2007), which was updated and adjusted to Swedish conditions (for more details, see Appendix A). The purpose of the budget is to provide an idea of the costs involved. The budget can change rapidly, depending for example on how the farmer's own labour is valued, whether calcium needs to be applied or perhaps whether a mechanical tiller is used when sowing.

Table 5. Estimated costs and outcomes in cultivation of wild-simulated ginseng. The origin of the values and more information regarding the budget can be found in Appendix A. Exchange rate 1 USD = 7 SEK

Wild-simulated cultivation; area 2000 m^2; harvest after 9 years		
Input	Cost (SEK)	Background for calculations
Seeds for planting	6996	5.66 kg (Persons & Davis, 2007) @ 1236 SEK/kg (Lewis[1])
Labour: Site preparation and planting	4550	25 hours (Persons & Davis, 2007) @ 182 SEK/h (Databoken, 2014)
Labour: Inspection and troubleshooting	36400	200 hours (Persons & Davis, 2007) @ 182 SEK/h (Databoken, 2014)
Labour: Digging roots	63700	350 hours (Persons & Davis, 2007) @ 182 SEK/h (Databoken, 2014)
Tools	350	Rake, axe, digging tool, assuming some equipment already at hand (Persons & Davis, 2007)
Backpack sprayer, pesticides	2100	
Drying	2800	Adaptation of an existing room as a drying area (Persons & Davis, 2007)
Energy for heat	278	7.73 SEK/kg dried root (Persons & Davis, 2007)
Yield	Income (SEK)	
Root yield	194688	36 kg (Persons & Davis, 2007) @ 5408 SEK/kg (Persons & Davis, 2007)
	Profit (SEK)	
Net profit after 9 years	77520	

4.2 Forest-grown cultivation

This is the method recommended by Persons (1994). It does not require large investments in shade constructions, but it is very labour-intensive, meaning that the main cost is the labour. The chosen site should be under mature hardwood. Ginseng does not grow well under pine trees, except for white and red pine. It is preferable to have little undergrowth and a thick layer of moist leaf litter (Persons, 1994). Naturally growing mature hardwood trees have a natural spacing that creates the right conditions for ginseng. It is better if the trees have a deep root system, so that they do not compete for nutrients and so that there is less risk of root damage when the ginseng beds are being prepared (Persons, 1994). Maple and elm are shallow-rooted trees, so deep-rooted trees such as oak, hickory and beech are preferred (Pritts, 1995). Although certain soil characteristics are preferred (section 3.2), according to Persons (1994) almost any forest floor can be improved regarding ginseng farming. For example, a dense soil can be loosened up by adding well-rotted organic matter, making it easier for air and water to move through the soil. When there is a heavy rain, the excess water must leave immediately, continuing down the slope or moving on through the soil to subsoil that lets the water through fast. One way to deal with this is by digging trenches between the sowing beds, although according to Pritts (1995) trenches are only necessary if the site is low-lying or poorly drained. The trenches should be the same depth as the tilling depth. Another method to avoid excess water is through raising the beds, i.e. adding material to (raise) the sowing beds. The height of the

[1] E-mail from Jeff Lewis, general manager at Ginseng & Herb Cooperative, Wisconsin, USA. 2013-12-12

sowing bed depends on the degree of the slope, with a steeper slope requiring less elevation of the bed, since water moves away quickly. Bed raising is connected to trench digging, since an easy way to dig trenches is to throw the soil onto the adjacent bed, thereby raising the level.

A small tractor can be used for preparing the soil in the forest, but this requires skill. It is important not to harm the trees, for example by destroying deep-lying roots, and to avoid dragging topsoil from the top of the slope. Persons (1994) mentions two types of implements that work successfully on ginseng farms, a mouldboard plough and a bog disc harrow. There are also customized bed makers, which are used in large-scale ginseng farming. An option for small-scale farmers or in difficult areas is to use a tiller. When the soil is tilled, soil is moved from the walkways to the beds and raked to the middle of the bed so that the centre is about 5-8 cm higher than the edges (Persons, 1994). Some farmers work fertilizer into their beds, while others claim that fertilizers can make the plants more vulnerable to diseases. It is also believed that fertilized roots look more like cultivated roots, which lowers the value (Persons, 1994). Well-rotted compost and manure can be tilled into the beds, although the manure has to be old and well-composted.

Persons (1994) suggests two ways of planting seeds. One is to use a hand-operated garden seeder with adjustable depth and spacing, which needs to be adapted for ginseng. The other way is to broadcast the seeds over the bed by hand and use soil from between the beds (the pathway/trench) to cover the seeds. In small-scale farming it is also possible to produce rootlets in a nursery and plant these in the beds by hand, starting at the top of the bed. Rows are made in the bed at 15 cm spacing and to a depth of 10-12 cm. After one row is made, the soil from the next row can be used to cover the rootlets in the first row. The rootlet has to be planted bud up, with the bud about 2-5 cm below the soil surface (Persons, 1994).

4.2.1 Cost of cultivating forest-grown ginseng

The production budget presented in Table 6 is based on a previous budget prepared by Persons and Davis (2007). The inputs and values can vary considerably depending on situation. For example, the net result depends on how work is valued. In the original budget, labour was valued at the equivalent of 70 SEK/hour (Persons and Davis, 2007). In the revised budget for Swedish conditions, a value of 182 SEK/hour was used, which is what a 19-year-old labourer with one year of farming experience would cost. As shown, changes in labour costs alter the budget radically, since forest-growing of ginseng is labour-intensive (Table 6).

The budget will also depend on the current ginseng price, which fluctuate significantly between years and within the year. The root price used in the present budget was an estimated 4635 SEK/kg (300 USD/pound)[2], as the current lowest price for forest-grown ginseng (Lewis[3]). In the original budget data (Persons and Davis, 2007), the estimated value was 1545 SEK/kg (100 USD/pound)[2]. Furthermore, the look of the roots affects the value, so forest-grown ginseng that looks like field-grown ginseng will get the same lower price as field-grown.

In this budget, seeds were not considered to be income. It was assumed that there is no way to compete with seed production from field cultivation, since production of seed in forest requires about 57 kg/ha, compared with 227 kg/ha in field cultivation. It would also be more expensive

[2] Exchange rate 1 USD = 7 SEK

[3] E-mail from Jeff Lewis, general manager, Ginseng & Herb Cooperative, Wisconsin USA. 2014-02-07

harvesting seeds in forest, as these have to be picked continuously to prevent them from being eaten. With field-grown ginseng, all berries ripen at the same time. Another reason is that it is a good option to dead-head the plants to increase root weight, so there is no production of berries/seeds.

Table 6. Estimated costs and outcomes in cultivation of forest-grown ginseng. More information regarding the budget can be found in Appendix B. Fencing was assumed not to be needed and tools were assumed to be already available. Exchange rate 1 USD = 7 SEK

Forest-grown cultivation; 6-year growing period; area 2000 m^2		
Input	Cost (SEK)	Background for calculations
Seeds	13472	10.9 kg (Persons & Davis, 2007) @ 1236 SEK/kg (Lewis[4])
Fungicides, herbicides, fertilizer, diesel, oil	7000	(Persons & Davis, 2007)
Tiller bought	10400	(Nima maskinteknik AB)
Labour: Site preparation and planting	54600	300 hours (Persons & Davis, 2007) @ 182 SEK/h (Databoken, 2014)
Labour: Care & maintenance	182000	1000 hours (Persons & Davis, 2007) @ 182 SEK/h (Databoken, 2014)
Labour: Harvest, seed and roots	118300	650 hours (Persons & Davis, 2007) @ 182 SEK/h (Databoken, 2014)
Garden seeder	525	(Persons & Davis, 2007)
Backpack sprayer	1750	(Persons & Davis, 2007)
Drying room; insulation *etc*.	4200	(Persons & Davis, 2007)
energy	1051	7.73 SEK/kg dried root (Persons & Davis, 2007)
Yield	Income	
Root yield	630496	136 kg (Persons & Davis, 2007) @ 4635 SEK/kg (Lewis[5])
	Profit	
Net profit after 6 years	237198	

If the field-grown ginseng were to be organically produced the budget would change slightly, with lower seed costs due to lower planting density and perhaps lower herbicide and pesticide costs (but of course organic alternatives are probably more labour-intensive, *e.g*. more weeding. The product would probably also attract a higher price on the Asian market, since it would be more wild-looking.

4.3 Field-grown cultivation under artificial shade

The most common way to produce ginseng in America is in the field under artificial shade, which can be carried out on a large scale and highly mechanized. It requires a high financial input, for example , according to research in Denmark about 720 000 SEK/ha (600 000 dkr/ha) are needed to establish and manage a ginseng crop (Madsen *et al*., 2001).The growing period is shorter, as the roots can be harvested after four years. On the other hand, the pressure of weeds and disease in this type of farming is great and pesticides and herbicides are essential. Moreover, as mentioned, the land cannot be used for ginseng farming again for a long time. Another aspect is the disease problem, which is greater in artificial shade farming than in forest farming. The shade reduces the air circulation and the open field makes it easy for fungal spores to thrive. The plants are often planted

[4] E-mail from Jeff Lewis, general manager, Ginseng & Herb Cooperative, Wisconsin USA. 2013-12-12

[5] E-mail from Jeff Lewis, general manager, Ginseng & Herb Cooperative, Wisconsin USA. 2014-02-07

in a dense stand, creating a humid environment that is ideal for diseases to spread (Persons, 1994). Artificially shaded ginseng crops are often heavily sprayed with fungicides to avoid or minimize fungal diseases. The weed problems are much greater in this type of farming and weeding is more important, since the weeds not only compete for nutrients, but also reduce air circulation and create an even more humid microclimate.

Some aspects are easier in open field conditions, for example bed preparation without the presence of tree roots is of course easier. Furthermore, fewer plants and berries are eaten by rodents. Another advantage of open field growth is the range of harvesting methods available, as it is much easier to use a modified potato digger (often used), than a shovel or spade fork, which is what the farmer has to rely on in the forest (Persons, 1994).

The artificial shade can be provided in several ways. In America, wood laths and polypropylene shade fabric are used (Persons, 1994). The shade is normally put up just before the seedlings emerge in the spring, but the preparations start in autumn. At planting time, the dimensions are calculated and the posts for carrying the shade construction are put up (Persons, 1994). At Flora Farm, a ginseng farm in Germany, a synthetic weave is used (Wischmann[6]) (Figure 2). The weave is hung on poles before being spread over the beds (Figure 3).

Figure 2. Artificial shade over ginseng beds at Flora Farm, Germany (photo: Author, 2014).

Figure 3. Shade netting being prepared at Flora Farm, Germany (photo: Author, 2014).

The soil organic matter content is normally high in the forest, but the situation in the field varies. If the site has been under fallow the organic content is probably high, but otherwise organic material might need to be added. One alternative is add manure, which is done by large-scale farmers in the USA. It has to be well-rotted and is associated with risks, *e.g*. it can change soil chemistry, it might contain weed seeds and it may increase root growth too much (Persons and Davis, 2007). Another option is to grow a cover crop that is tilled in before planting (Persons and Davis, 2007). Some growers incorporate forest soil (Persons and Davis, 2007), which is naturally rich in humus, but also possibly with other positive ingredients from the forest that are not fully known, for example fungi

[6] Interview with Gesine Wischmann, during visit to Flora Farm, Bockhorn, Germany. 2014-04-04

and bacteria beneficial for ginseng (see section 6.2). It is also possible to use the natural supply of organic matter for ginseng, namely leaves and bark from forest (Persons and Davis, 2007).

The preferred location for field cultivation of ginseng is again on a gentle slope. To prepare the site, grassland has to be ploughed on and off during the summer to reduce weed pressure, or many farmers also use pesticides (Persons, 1994). Planting is done by hand, garden seeder or machine. On a small-scale level, seedlings can be transplanted from a nursery. A spacing of 15 cm is often used, as a closer spacing will result in a smaller root. A spacing of 5 cm between seeds creates spindly looking roots, whereas a broader spacing ensures larger roots, less disease, less labour, more berries and less work with a cultivator (Pritts, 1995). A study by Konsler (1982) showed that a spacing between plants of 22 cm (9 inches) produces the largest roots in a four-year field cultivation system under artificial shade. This broader spacing is also beneficial for plants with a longer growing period than 4 years, for example plants grown for long-term ginseng seed production.

4.3.1 Cost of cultivating field-grown ginseng under artificial shade

The suggested budget for a small-scale conventional field cultivation system under artificial shade shown in Table 7 is based on a previous budget prepared by Persons and Davis (2007). The figures have been updated to current values and adjusted to Swedish circumstances. The net profit of the budget is radically dependent on the current price of field-grown ginseng, which can rapidly change. The current ginseng price is quite high, 1313 SEK/kg (Lewis[7]), making this farm a profitable business. However, in the original budget the price was significantly lower, 309 SEK/kg (20 $/pound[8]) (Persons and Davis, 2007), suggesting low or no profit. Thus, the world market price is crucial.

[7] E-mail from Jeff Lewis, general manager, Ginseng & Herb Cooperative, Wisconsin USA. 2013-12-12
[8] Exchange 1 $ = 7 SEK

Table 7. Estimated costs in cultivation of field-grown ginseng under small-scale artificial shade conditions. More information regarding the budget can be found in Appendix C. Assumptions made for this budget were that land and tools were already owned and fertilizer was not needed. Exchange rate 1 USD = 7 SEK

Field cultivation; small scale; 4-year growing period; area 400 m^2		
market price and	Cost (SEK)	Background for calculations
Seeds for sowing	4450	3.6 kg (Persons & Davis 2007) @ 1236 SEK/kg (Lewis[9])
Mulch	280	(Persons & Davis, 2007)
Labour	72800	400 hours (Persons & Davis, 2007) @ 182 SEK/h (Databoken, 2014)
Tiller	1215	Rented at 450 SEK/day (CS Maskin AB) for 3 days
Fungicide sprayer	700	(Persons & Davis 2007)
Energy for drying	696	7.73 SEK/kg dried root (Persons & Davis, 2007)
Shade construction	8610	(Persons & Davis, 2007)
Fungicides/pesticides	315	(Persons & Davis, 2007)
Yield	Income (SEK)	
Seed yield	22248	9 kg/year x 2 years (Persons & Davis, 2007) @ 1236 SEK/kg (Lewis[9])
Root yield	118170	90 kg (Persons & Davis, 2007) @ 1313 SEK/kg (Lewis[9])
	Profit	
Net profit after 4 years	51353	

If the field cultivation were to be organic, seed costs would be less due to the lower density, but the crop would probably require a lot more labour for weeding. The yield would be lower than conventional, but in the organic niche market it would make a higher price. Organic farming is usually much less intensive than conventional, with about 0.7 kg (1.5 pounds) of seed per 400 m^2 (0.1 acre) (Persons, 1994).

4.4 Organic farming

It might be difficult to compete in ginseng cultivation as a small grower without access to a niche market (Persons and Davis, 2007), and the organic market could provide such an option. Of course, there is also the environmental aspect of not adding chemicals to the environment. Standard American ginseng farming uses a large amount of fungicides, many of which are not permitted in Sweden (Spångberg Andersen, 2002). There is a possibility that it will be difficult to obtain pesticides, at least this is the situation in Denmark where permits have to be obtained (M. Jensen, pers. comm. 2014[10]). The pesticides have to be “allowed for the product” or “off-label use” or “minor use” approved, and these permits have to be bought, which might not be financially justifiable for such a small-scale product as ginseng.

Another aspect in favour of organic ginseng farming is the freedom from chemical residues, which of course is of customer interest regarding a product used for health improvement. Finally, ginseng normally benefits from antagonistic microflora (described in section 6.2), beneficial bacteria and fungi that help protect the plant, and this balance might be interrupted with fungicides.

[9] E-mail from Jeff Lewis, general manager, Ginseng & Herb Cooperative, Wisconsin USA. 2013-12-12

[10] E-mail from Martin Jensen, Dept. of Food Science, Aarhus University, Denmark. 2014-01-30.

Today, due to the great disease pressure on ginseng, most large-scale ginseng plantations in America depended on fungicides and herbicides (Persons and Davis, 2007). According to Henrike Rodemeier[11], a German ginseng farmer, fungi are a major problem in Germany too. On Flora Farm, where the variety grown is *Panax ginseng* (Asian ginseng), organic farming was attempted at an early stage but eventually abandoned due to fungal diseases. Henrike[12] described how an entire ginseng field could be infected in a matter of hours. However, in spite of the challenges with fungal diseases, there are examples of successful organic farms. One large-scale, mechanized organic ginseng farm is Sego's Herb Farm in America (Sego's Herb Farm, 2014). In Denmark, Kongshave Ginseng farm also grows this crop without pesticides and herbicides (Kongshave Ginseng, 2014).

4.5 Fertilization

One way of adding nutrients to the soil is by using manure. Manure is normally used only if mixed with compost materials and aged for a year. Compost also adds much needed organic material to the soil (Pritts, 1995). In Korea, pulverized granite, bone meal and leaf mulch are used as fertilizers (Pritts, 1995). In organic farming, the growers rely on compost and organic-based fertilizers (Pritts, 1995), although seaweed or sea fish solutions can also be used (Persons, 1994). It is possible to use foliar fertilizers, which are sprayed on and absorbed by the leaves, for which both organic and conventional options are available (Pritts, 1995). Fertilizers can also affect the taste of ginseng (Pritts, 1995), which could be of interest especially when growing this crop for the Asian market.

4.6 Weeding

As mentioned earlier, it is common to till the ground repeatedly during summer and autumn prior to planting in order to get all weed seeds to germinate (Persons and Davis, 2007). Most artificial shade growers also weed during the growing season to reduce competition for nutrients (Pritts, 1995). Weeds are usually a much greater problem when grown in the field, and weeding needs to be done early in the summer, at least when the plants are young (Persons and Davis, 2007). It is easier to pull up weeds by their roots under wet conditions, but wet conditions are also favourable for disease organisms, which can be transported with the root (Persons, 1994).

Forest growers are divided on the weeding issue. Some believe pulling weeds can bring disease spores to the surface and there is also a belief that weeds reduce the risk of disease by the diversity they bring. These growers may wait until the weeds are taking over the garden before pulling them out or cutting them just above the ginseng level with a weed trimming machine (Pritts, 1995). Although weeding might disturb the natural balance, a dense weed population is not natural (Persons, 1994).

4.7 Mulch

The ginseng plant needs a layer of mulch. Naturally, this consists of leaves supplied by the trees in the forest, but in the open field it has to be applied (Persons, 1994). The purpose of the mulch is to protect seeds from drying out, to lower soil temperature by reflecting heat and to reduce the effects of freeze-thaw cycles (Pritts, 1995). It also reduces weeds and prevents erosion (Persons, 1994). The mulch affects soil rootzone properties such as temperature, moisture, microbiological activity and soil physical and chemical characteristics (Konsler, 1982). Mulch can alter the soil nutrient levels and

[11] Interview with Henrike Rodemeier, ginseng farmer, Bockhorn, Germany. 2014-04-04
[12] Interview with Henrike Rodemeier, ginseng farmer, Bockhorn, Germany. 2014-04-04

thereby affect yield (Persons, 1994). It is therefore important to have knowledge of the different types of mulch and how they affect the soil. Examples of mulches are market price and: hardwood leaves, chopped straw, hardwood bark/sawdust mixture, and compost. The type recommended by Persons (2004), at least for forest growers, is hardwood leaves, the natural mulch in woodland gardens. It is handy and the natural mulch for ginseng. However, oak leaves need to be shredded first and contain tannic acid (Persons, 1994).

In field farming, the most common mulch in the USA for ginseng is chopped straw, *e.g*. oat straw, barley straw and wheat straw. It is easy to use as there are machines designed for spreading different bales and companies specializing in this (Ministry of Agriculture British Columbia, 2003; Persons and Davis, 2007). According to Ministry of Agriculture British Columbia (2003), seedlings can emerge through about 10 cm of straw mulch, and a mulch layer of between 5 and 10 cm is recommended. Straw has been used in Danish studies and is also used on Flora Farm, Germany. Figure 4 show straw-covered beds for 2- to 4-year- market price and old ginseng, while Figure 5 shows beds with first-year ginseng. According to Henrike Rodemeier[13], the mulch layer is thinner on these beds for easy emergence of seedlings.

Figure 4. Straw mulch on ginseng beds at Flora Farm, Germany (photo: Author, 2014).

Figure 5. Straw mulch on first-year emerging ginseng seedlings at Flora Farm, Germany (photo: Author, 2014).

While straw is easy to use in large-scale farming, Persons and Davis (2007) recommend shredded leaves, hardwood bark/sawdust mixture or compost for the small-scale farmer. This does not decompose as quickly as straw and does not attract slugs. According to a study by Konsler (1982), the mulch which produces most root weight gain is a mixture of oak sawdust and oak bark mulch. The smallest roots in that study were produced using wheat straw or hardwood leaves as mulch. However, in organic growing a disease-free crop might be of more interest than root size. A study in Poland (Lublin area) has shown that fungal proliferation can be reduced by using a type of mineral mulch (trademark 'Agran' in the study) instead of straw. It enhances the growth of fungi-repelling bacteria and reduces the growth of fungi (Pastucha and Koodziej, 2008). The ingredients of this mulch are not revealed in that study. Mulch can also change soil properties, as shown in a study by Konslers (1982) where oak bark/sawdust gave by far the greatest increase in organic matter, pH and nutrients such as calcium, magnesium, phosphorus and potassium.

[13] Interview with Henrike Rodemeier, ginseng farmer, Bockhorn, Germany. 2014-04-04

Mulch needs to be applied immediately after planting. The thickness of the layer depends on location and the material used. The more northerly the site, the thicker the layer needed, as it has to be thick enough to prevent the soil temperature from going below -4 °C. In addition, loose mulch, such as straw, settles during winter to half the initial thickness or less (Ministry of Agriculture British Columbia, 2003). The thickness of the mulch layer also varies depending on material and cultivation system (Tables 8 and 9).

Table 8. Thickness of the mulch layer (in autumn, i.e. before settling) required for forest cultivation of ginseng, according to experiences in North Carolina, USA (Persons and Davis, 2007)

Type of mulch for forest-grown ginseng cultivation	Thickness
Leaf litter	5-7. 5 cm
Bark/sawdust mixture	2. 5 cm
Straw	7.5-10 cm

Table 9. Suggestions on mulching in small scale field-grown ginseng cultivation (Persons and Davis, 2007)

Type of mulch for small-scale field ginseng cultivation	Height
Bark/sawdust mixture	market price and
Compost	2.5 cm
Shredded leaves	2.5 cm

To grow ginseng further north in the USA, the thickness of the mulch layer should be doubled (Persons and Davis, 2007). If thicker layers are needed, parts of the mulch have to be removed in spring in order for the ginseng to emerge through. The mulch layer needs to be checked every few weeks to make sure all areas are covered and that it is not too thin. The pathways should be kept clear of mulch to let water through (Persons, 1994).

4.8 Obtaining seed and root

Since the ginseng plant is controlled by CITES, there are regulations to consider when buying and selling the root. Seeds and leaves, on the other hand, are not covered by this convention (Persons and Davis, 2007) and are easier to import. Importing seeds to Sweden may not be so easy, however. Two different American internet shops that were approached for this study announced that they did not sell ginseng internationally. According to Eidus[14], there are different reasons for this. One seems to be the need for the seeds to be kept moist, *i.e*. a transportation problem, and in the USA the seeds are transported overnight or kept refrigerated. Other reasons are availability of ginseng seeds, which has been low lately, and also the feeling of wanting to keep the seeds in the USA, where it is needed and where there are growing conditions to which the plant is adapted. Since there are ginseng growers in Denmark it is possible to buy seeds from Denmark, for example from Kongshave Ginseng (Kongshave Ginseng, 2014). An aspect to keep in mind when buying seeds is that many of the diseases that attack ginseng might not exist in Sweden as yet. Since seeds can be carriers of fungal diseases, Persons (1994) recommends that the seeds be treated for diseases, in order to avoid contaminating the growing site unless the supplier is guaranteed disease-free.

[14] E-mail Robert Eidus, North Carolina Ginseng & Goldenseal Co. 2013-09-30.

Normally, the seeds are sold stratified (see section 4.9) and it is best to plant them straight away. If they need to be stored over winter, they can be kept in a fridge or in a mix with moist sand, but they need to be kept cool, about 2-10 °C (to break dormancy). If kept in the fridge, a few drops of water should be added every day or every second day (Persons, 1994).

4.9 Stratification

Stratification is the simulation of nature's process to get the seeds to germinate. This is done by letting the seeds go through first a warm period and then a cold period. Unstratified green seeds can be planted directly after harvest, as soon as they are dry and pulp-free, and they will germinate after 18-20 months. The cold period needed to break seed dormancy is described by Snow and Snow (2009) as a minimum cold cycle of 45 days with temperatures below 2 °C and by Jensen[15] as 3-5°C for 4-5 months. Many growers choose to store the seeds in a stratification box (see below) for a year, as there is less risk of them being eaten by rodents and it keeps the soil free. The seeds are then planted in the autumn, a year after seed harvest, traditionally just when the trees lose their leaves (Persons, 1994). Danish studies have shown that it is possible, through hot and cold treatment, to make ginseng seed germinate in the first spring following harvest. The dormancy is broken by 4-5 months of heat treatment at 20 °C of moist seed mixed with peat, followed by a cold treatment of 4 months at 3-5 °C (Jensen, 2001).

Stratification in America is usually done using a wooden box about 0.3 m deep. The bottom is covered with a wire or screen mesh for drainage. Fine sand and seeds are placed in layers, starting with sand in the bottom and with the same volume of sand and seeds. The top of the box is also a wire or screen mesh (Persons, 1994). The box is buried in a shaded location and covered with soil. The seeds then experience the natural seasonal changes until planting in the autumn (Pritts, 1995). According to most sources, ginseng seeds need to be kept moist during the whole storage period. Jensen (2002) has shown that this is not the case and in fact that it is only towards the end of the cold period and before germination has started that moisture becomes necessary. This opens the way for new storage and transportation possibilities.

4.10 Harvesting and drying

Seed harvesting can begin from the third year, when the plant starts to flower. If seeds are not of interest, the flowers can be snipped off to force the growth into the roots. Forest-grown berries ripen over a period of several weeks (Pritts, 1995) and should be picked as they ripen, about once a week (Persons, 1994). Field-grown berries ripen simultaneously.

The root age at harvest depends on the chosen method of cultivation and growing conditions. Open field-grown roots are often harvested after 4 years, forest-grown after 5-6 years and wild-simulated after 6-10 years, depending on the size of the roots (Persons, 1994). According to Pritts (1995), the forest-grown ginseng should be harvested after 6-8 years and wild-simulated after 8-15 years. The roots should be harvested in the autumn, after the tops have started to wilt. For small-scale farming, manual harvesting may be the only option, where the roots are carefully dug up with shovel, spade or fork (Persons, 1994). In large-scale cultivation machines are used, for example a machine similar to a potato-digger (Persons and Davis, 2007). A ginseng farm in Germany uses a device to move below

[15] E-mail from Martin Jensen, Dept. of Food Science, Aarhus University, Denmark. 2014-05-06

the roots, loosening the soil, and then harvests the roots manually (Rodemeier)[16]. The amount of ginseng roots produced differs between production systems. In an artificial shade system, the aim is about 8.7 ton/ha fresh root and 2.5 ton/ha dried root (Pritts, 1995)[17]. The maximum production in forest growing is 1.3 ton/ha dried root[8], due to wider spacing and the competition for nutrients (Pritts, 1995).

The roots need to be dried immediately after harvest. Drying is a critical process that takes between a few days (small roots) and six weeks. It should be done in a warm location with good air circulation and control of the air humidity. It is very important that drying is done correctly, as moulds, mildew, dark skin and caramelization of the interior are problems that can arise due to inappropriate drying. The root can also be dried too fast, creating brown rings inside the root (Persons and Davis, 2007). Due to problems with root drying, most buyers in America are switching to buying green, undried roots, rather than dried ginseng. This enables them to control root quality better (Randall[18]). The dry roots are placed in cardboard boxes and stored in a dry place at room temperature or a little cooler. The roots need ventilation (no plastic) and no dampness (Persons, 1994).

5. Climate

5.1 Latitude

American ginseng (*Panax quinquefolium*) grows naturally from 30 to 50°N in the USA (Persons, 1994) and reaches its northern limit in southern Quebec, Canada, at about 53°N, just north of the city of Quebec. In Canada, ginseng occurs in south-western Quebec and southern Ontario. The south Swedish border (Trelleborg), has latitude 55°N and Stockholm has latitude 59°N (itouchmap.com, 2014). Based on this criterion alone, Sweden would appear to be too far north for ginseng production, but the proximity to the north Atlantic and the prevailing west to south-west winds make the Swedish winters warmer than suggested by the latitude (SMHI, 2009).

5.2 Winter

The contractile root of ginseng ensures that the rhizome and new bud are kept below the surface and protected from cold, but when the soil temperature falls below -4 °C the root is injured. Soil temperatures lower than 11 °C severely injure the root and those below 17 °C kill the root (Archibold *et al*., 1998). The seed can tolerate temperatures down to -15 °C if the moisture content is low (Persons, 1994).

Ginseng is hardy from USDA zone 3 (Faurot *et al*., 2004.) in the American zone system showing the winter temperature minimum. Ginseng could theoretically be grown (according to this criterion) in regions where the winter temperature goes down to a minimum of -40 °C, which includes the most northern parts of Sweden (Figure 6).

[16] Interview with Henrike Rodemeier, ginseng farmer, Bockhorn, Germany. 2014-04-04

[17] Field-grown: 3.5 ton fresh root, 1 ton dried root per acre. Forest-grown: 0.5 ton dried roots per acre

[18] E-mail from Jesse A. Randall, Iowa State University, Associate Professor & Extension Forester. 2014-02-07

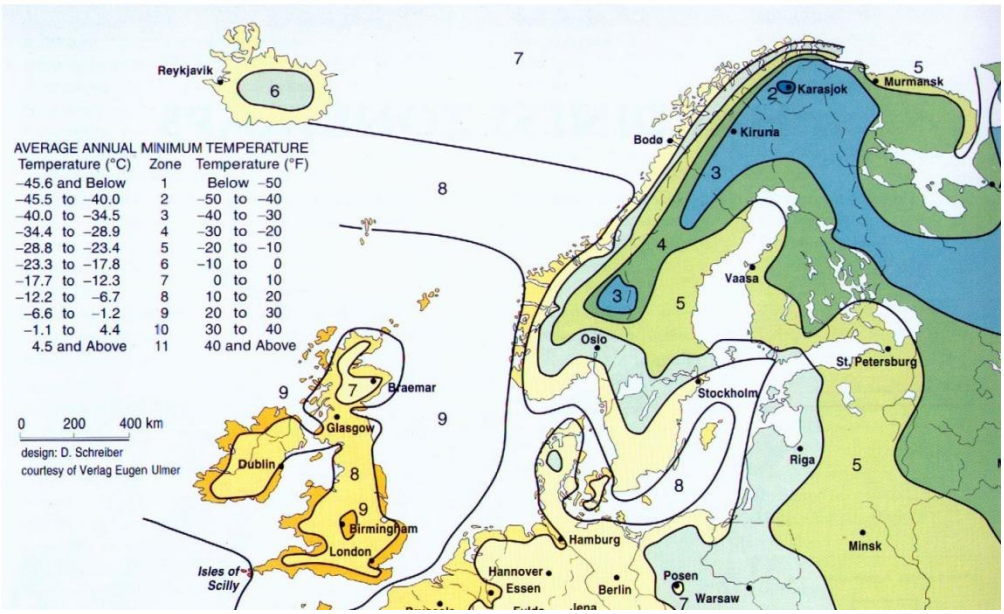

Figure 6. Hardiness zones of Europe (D. Schreiber, 1984.)

An early snowfall can form an insulating cover over the ground, which mostly keeps the ground in the northern parts of Sweden from getting colder than a few degrees below freezing at a depth of 20 cm (Löfvenius Ottosson, 2013). Studies in Canada have shown that snow is a good insulator due to trapping of solar radiation and release of latent heat, *i.e.* it works as natural mulch, and that snow and soil are better insulators than straw. However, a snow cover cannot be guaranteed and straw has the benefit of capturing snow when it does arrive (Archibald *et al*., 1998).

In winters with late snowfall, soil temperatures can go lower than -4 °C in northern Sweden, and it can be almost as cold in the ground as in the air. Soil temperatures are coldest closest to the surface. Of course, with ginseng there is a protective mulch layer that prevents a part of the temperature decline. The possibilities of growing ginseng under cold conditions have been investigated in Saskatchewan, Canada, where winter air temperatures can fall below -40 °C. The results from that study indicated that a straw layer of 40 to 115 cm, combined with normal snowfall, could prevent the soil temperature from falling below 4 °C, although even more mulch could be needed in the event of intense cold spells. The conclusion from that study was that the winter conditions in Saskatchewan might be too severe for reliable ginseng production (Archibold *et al*., 1998).

5.3 Spring frost

Frost after germination can damage the new ginseng seedlings. Spring frost does not occur often in America, but when it does the damage can be great. Seedlings that have reached above the mulch will be damaged and might not survive (Schooley and Proctor, 2003). An experience from the late spring frost in Ontario in 2002 was that crop damage was concentrated to low-lying areas, which collect cold air. There have also been reports of plants escaping undamaged in spring frost due to heat storage in the soil/mulch system (Schooley and Proctor, 2003). After undergoing the necessary cold period, ginseng seed starts to germinate at soil temperatures of 3-5 °C. In Denmark, these soil temperatures are reached in late April or early May, and this is when the seedlings emerge. Danish ginseng production (which has been underway for 10 years) has not yet had any problems with

spring frost (Jensen[18]). In Ontario, southern Canada, the last date (mean value) for spring frost is May 12 and spring frost is not common there (Schooley and Proctor, 2003).

Swedish soil temperatures have been measured continuously at different locations by the Swedish University of Agricultural Sciences (SLU) and are reported annually. The temperature is measured at a depth of 20 cm at different locations in Sweden. The date of the start of the vegetation period (when the soil temperature reaches 5 °C) is recorded (2012) (Löfvenius Ottosson, 2013). Comparing this date with the date of the last frost for the same area (SMHI, 2006), it was found that for all stations, the vegetation period (and ginseng germination) starts before the average last frost (about 8-20 days previously). These data show the possibility of spring frost in Sweden and the risks of this need to be further investigated. The root growth of second-year and third-year ginseng is initiated when the spring soil temperature exceeds 8 °C (Proctor and Bailey, 1988), and thus only the first-year seedlings are exposed to this risk.

5.4. Summer temperatures and local adaptation

The warm period needed is about 2-3 months, during which the germ develops fully and the seed will then germinate at low temperature in the following spring (Jensen[19]), while summer soil temperatures of 15-18 °C are optimal for root growth (Lee *et al*., 1986). At lower latitudes, germination occurs after the development of the forest canopy, but in more northerly regions such as Quebec both events occur simultaneously. As a result, the shoot develops rapidly and is fully developed in about a month (Proctor and Bailey, 1987 *cit*. Fournier *et al*., 2004).

Studies have shown strong indications of ginseng being a species locally adapted to temperature on population level, *i.e*. ginseng populations have over time adapted to local temperatures (Souther and McGraw, 2011). This may need to be considered when procuring seeds for planting, since temperatures outside the population-level thermal niche will reduce growth.

5.5 Rainfall

Ginseng requires at least 500 mm rain (Pritts, 1995; Snow and Snow, 2009). According to the SMHI database for rainfall (2012 data), all parts of Sweden receive annual rainfall of at least 500 mm (min 500 mm, max 1300 mm) (SMHI, 2012.).

5.6 Light

Ginseng is a shade-loving plant and according to Persons (2007), 78% shade is optimal for growing ginseng on most soils. Over a certain amount of sunlight, photo inhibition occurs (light-induced damage) and photosynthesis does not function fully. Photosynthesis in ginseng operates at optimum speed at a photon flux density of 200 µmol/m^2/s (Proctor, 1980). This optimum is often not met in the natural environment, under the forest canopy. Studies have shown that light reaching the forest floor is about 4% of full sunlight in northern hardwood forests (Beaudet *et al*., 2004) ,which is much lower than the light saturation point for shade plants (Pfitsch and Pearcy, 1989). The solar radiation that reaches the plant can be optimized under artificial shade. In Danish studies, 'shade tents' providing 60% shade has been used (Figure 7).

[19] E-mail from Martin Jensen, Dept. of Food Science, Aarhus University, Denmark. 2014-05-06

Figure 7. Ginseng cultivation in a shade tent, Denmark (photo: Martin Jensen, n.d).

Since Sweden lies at higher latitude than existing ginseng farms, the need for shade might differ. The intensity of solar radiation decreases with latitude, *i.e*. Sweden receives less intense radiation than the normal growth habitat of ginseng. This is due to the lower insolation angle, spreading the radiation over a larger area. Lower sunlight intensity suggests that the need for shading at high latitudes could be less than found optimal for lower latitudes, i.e. less than 78 %. Another effect of high latitude on sunlight is the longer days. Sweden receives more hours of solar radiation per day than the normal growth habitat. How this affects ginseng production should be investigated further. Another aspect is the insolation angle, which is lower at higher latitudes and affects for example how much radiation can enter through gaps in the canopy.

Incoming radiation can be calculated to estimate the optimal percentage of shade for ginseng grown under artificial shade in Sweden. To find out the radiation level under a forest canopy, the transmission rate through the canopy and the changing (daily and seasonally) incoming solar radiation must be known. The percentage of radiation to reach the forest understory can be calculated. The reduction in radiation on passing through the canopy depends on the physical aspects of the canopy (leaf size *etc*.), gaps (tree fall) and sun flecks (gaps in the canopy) and can be estimated using factors to account for these. These estimations result in a ratio between incoming radiation and radiation below the forest canopy, *i.e*. the transmission rate. The incoming radiation depends on cloudiness, latitude, season and shifts during the day.

The quantity of radiation is not the only aspect concerning ginseng and light. There is also the subject of quality. The forest canopy alters the incoming radiation. The leaves absorb blue, red and UV radiation, leaving the plants below with radiation which differs from that reaching plants in direct sunlight (Fournier *et al*., 2004). Sun flecks, the gaps between the leaves, have a negative effect on germination of American ginseng (Wagner and McGraw, 2013), suggesting that a suitable light habitat (low in direct light) is important for germination.

5.7 Deciduous forest

Since ginseng grows naturally under deciduous forest and does not grow well under pine trees, it is of interest to know **where** (how far north) and to what extent it would be possible to consider forest farming in Sweden. The most widespread deciduous trees in Sweden are lime and elm, which grow up to about central Sweden, while oak, ash and maple reach the southern third of Sweden. Beech covers about one-quarter of Sweden. This suggests that the possibilities for forest farming of ginseng would be limited to the southern half of Sweden. The area of propagation for the different trees can be seen specifically at http://www.skogforsk.se/sv/KunskapDirekt/Adellov/Adellovskog-i-Sverige/Har-finns-adellovskogen/. Swedish forests only comprise a small amount of deciduous forest, the remainder consisting of pine and spruce. Of the deciduous forests, oak and beech are in the majority and yet only represent about 1.5% of Sweden's total growing stock. The limited amount of deciduous forest also limits the area suitable for forest farming of ginseng. In Skåne, the most southerly region of Sweden, deciduous forest occupies a greater proportion, 30% of the growing stock (Skogforsk, 2014).

5.8 Experiences in Denmark and Sweden

In Denmark, a four-year study (1996-2000) investigated *Panax quinquefolium* and the possibilities for growing it in Denmark. The seeds were sown directly on the field with an ordinary seed drill in September. The field was covered with straw to a depth of 5-10 cm. The results show that American ginseng can be grown in Denmark and has the same concentrations of active substances as ginseng grown in Canada (Jensen, 2001). The yield levels reported in the USA (2.5-3.5 ton) were not achieved in the Danish study, but it is believed that they are possible (Madsen, 2003). The fungal disease problems that are common in USA were not experienced in the Danish study. However, a problem that was experienced was slugs, from which the crop needed to be protected (Madsen, 2003).

A study of Danish ginseng cultivation in a forest of ash and beech was not successful and the failure was suggested to be due to the wrong location. The ginseng plants could not keep up with other plants. Pests were also found to be a problem. Fungi were not found but insects, for example aphids, damaged the plants. Large, shallow tree roots were found to be a great obstacle to ginseng bed making and harvest. The conclusions drawn were that the right location needs to be chosen and that it needs to be free from slugs, well-drained and with little or no below-canopy vegetation (Madsen *et al*., 2001).

In Sweden, there have been some attempts at studying ginseng cultivation, but to the best of my knowledge they have been abandoned. Studies at Balsgård Kristianstad, SLU, were planned about 20 years ago. Plants were produced in pots and replanted in the field, but according to Rumpunen[20], the research lost its funding and was not followed up.

5.9 Species suitable for Swedish conditions

The two varieties that are commercially interesting are *Panax ginseng* (Korean ginseng) and *Panax quinquefolium* (American ginseng). Both varieties are grown in Denmark and Germany (Jensen[21]),

[20] Kimmo Rumpunen, Department of plant breeding, Swedish University of Agricultural Sciences. 2013-10-21

[21] E-mail from Martin Jensen, Dept. of Food Science, Aarhus University, Denmark. 2013-10-08.

suggesting that they could both be cultivated in Sweden. The varieties have different health effects, which mean that there could be room for both in the health food business.

A factor in favour of American ginseng is that it grows quickly and can be harvested after four years (field-grown), while Korean ginseng requires about six years or more. Furthermore, it could be easier to obtain seeds and roots of American ginseng as opposed to Korean. Jensen[22] also suggests that Korean ginseng could be slightly more sensitive to freezing. According to Wischmann[23], American ginseng is also easier to produce. It was chosen for Danish studies since it attracts a higher price than the Korean variety (Madsen, 2003).

On the other hand, one major advantage of Korean ginseng is that this is the only species so far that can be marketed and sold as an herbal medicine (see section 7.3). It is also the dominant variety on the health product market in Sweden. This suggests that Korean ginseng is familiar and easier to market.

6. Fungal diseases and rodents

Fungal diseases are a major problem in find cultivation of ginseng under artificial shade. The less the production method resembles the natural growing system, the more problems there are with fungi. In other words, growers of wild-simulated ginseng often do not experience any significant problems and forest-grown producers experience slightly more problems. The three basic disease types are root rot, blight and damping-off. *Alternaria panax* is an example of a fungus that can cause all three diseases (Persons, 1994).

Problems with fungi increase when air circulation is low, as can occur under artificial shade. Above all, the problem increases with plant density. The closer the plants are together, the easier it is for the fungal organism to spread (Persons, 1994). The humidity and temperature also tend to be slightly higher in artificial shade growth, which promotes fungi (Pritts, 1995).

6.1 Examples of pathogen fungi and fungal diseases

The most frequent fungal pathogens of American ginseng are *Cylingrocarpon destructans*, *Phytophthora*, *Alternaria alternata*, *Botrytis cinerea*, *Fusarium* species and *Rexocercosporidium* (Punja, 2011). *Alternaria* and *Phytophthora* are a particularly serious threat. *Alternaria panax* is a fungus that can spread via the seed, mainly attacks the leaves and can destroy large areas of ginseng in a short time (Jensen, 2001). It is also spread with airborne spores, stimulated by moisture (Pritts, 1995). Alternaria blight is caused by this fungi. *Phytophthora cactorum,* on the other hand, attacks the roots and is a dangerous soilborne fungal disease (Jensen, 2001). Phytophthora has been detected in Denmark; a ginseng farmer at northern Fyn lost his whole crop to this fungus (Jensen[24]). It is also possible that this is the fungus which has been problematic for the German ginseng farm, Flora Farm. The fungi described by Rodemeier[25] was associated with growth of tomatoes and potatoes in that if these crops were grown nearby, an infection in the ginseng crop was more likely.

[22] E-mail from Martin Jensen, Dept. of Food Science, Aarhus University, Denmark. 2013-10-08
[23] Interview with Gesine Wischmann, Flora Farm, Bockhorn, Germany. 2014-04-04
[24] E-mail from Martin Jensen, Dept. of Food Science, Aarhus University, Denmark. 2014-05-05
[25] Interview with Henrike Rodemeier, ginseng farmer, Bockhorn, Germany. 2014-04-04

Another example of a fungal disease is damping-off, which attacks young plants and causes the plant to wilt in a few days after infection, while older plants can resist. The fungi attack the stem under the mulch early in the season, when it is still cold and wet and the disease progression ends in plant and root death (Persons, 1994). Root rot is also a common disease in America, where it causes losses of about 20-30% and will return the following year if the roots are not dug up (Persons, 1994).

6.2 Preventative measures

According to Punja (2011), there are not many options for ginseng farmers in dealing with fungi. The options available are to use fungicides or to make soil improvements. It is common among growers to use fungicides (Pritts, 1995), and is believed to be necessary by many. One suggestion is to apply agrochemicals for disease control about 9 times per season (Oliver, 1998 *cit*. Proctor, 2003). Punja (2011) claims that the non-chemical approaches need to be researched in more detail and that there could be ways to reduce the use of fungicides, referring to organic production as a niche opportunity for the future. Punja (2011) also suggests development of environmentally benign methods, such as the use of biological control agents and green manure/cover crops.

As mentioned, root pathogens are promoted by moisture. Moisture can be avoided by growing ginseng on raised beds, providing enough space between plants, keeping a clear area surrounding the plantation and controlling weeds (Persons, 1994). Other preventative measures include making sure the soil is as free as possible from fungi before planting, and not growing ginseng after *e.g*. potatoes or tomatoes, which are themselves sensitive to *Phytophthora* (Jensen[26]). The soil nutrient status should also be checked. Another precaution sometimes used in organic farming is interplanting (Persons, 1994).

Green manure can be beneficial for the antagonistic microflora (Punja, 2011), for example bacteria that suppress the pathogenic fungi. Bacteria such as *Bacillus* spp. and *Tricoderma* spp. have an antagonistic effect on fungi as they are saprobionts, *i.e*. feed on the fungi. Another beneficial bacterial species suggested to contribute to pathogen inhibition is *Pseudomonas* spp. (Pastucha and Koodziej, 2008). According to studies by Pastuch (2008), it seems that the amount of fungi in the soil increases for every year ginseng is grown and the opposite occurs to the antagonistic bacteria, where there is a decrease. The choice of mulch can affect the level of antagonistic bacteria. The population of soil microorganisms is influenced by organic compounds of easily oxidized carbon present in organic fertilizers and crop residues (Pastucha and Koodziej, 2008). Hence, adding mulch to the soil affects the populations of microorganisms. In a study by Pastuch (2008), a mineral mulch used (containing fly ash, betonite, coal dust and perhaps more ingredients, reduced growth of fungi and increased growth of beneficial bacteria.

Another part of the antagonistic micro flora consists of beneficial soil fungi, with which ginseng growing in woodlands is considered to have a symbiotic relationship. The fungi utilize sugars from the feeder roots and in turn produce antibiotics for some soilborne pathogenic fungi and facilitate nutrient uptake (Persons and Davis, 2007). Research on Korean ginseng has shown that ginseng

[26] E-mail from Martin Jensen, Dept. of Food Science, Aarhus University, Denmark. 2014-05-05

growth can be enhanced by inoculating the soil with arbuscular mycorrizal fungi, which improves mineral nutrient uptake and soil structure in the mycorrhizosphere (Cho *et al*., 2009).

6.3 Disease control

Person (1994) recommends checking the soil for nutrients to identify any deficiencies. He also suggests sending a tissue sample for identification. Other actions can be to remove the mulch and diseased tops from the infected area, which is especially important for blight and root rot. Spores can survive through the winter in plant material and attack again in next growing season. Some farmers replace all mulch at the end of every growing season, while the tops of wilting plants can also be removed as a preventative measure (Persons, 1994). In order to shield the area, a ditch can be dug above and below the bed (Persons, 1994). Jensen[27] suggests removing infested plants every day and perhaps even soil if necessary, since *Phytophthora* can survive in the soil for a long time. Although many farmers rely on fungicides, there are alternatives, for example the use of diluted chamomile tea, both when the ginseng is attacked and as a preventative (Persons, 1994). Other suggestions are to approach the infested bed last, when moving through the fields, to avoid spreading spores.

6.4 Rodents

According to Persons (1994), rodents are not interested in ginseng roots, although they may damage the roots anyway. Rabbits can harm the plants when making a path over the crop, moles can dig in the beds and mice and voles might eat the ginseng roots. Larger animals such as wild boar, deer and dogs can be kept out with a fence. Slugs might be a problem, as has been experienced in Danish studies (Jensen, 2001) and in German ginseng production (Rodemeier[28]).

7. Market and regulations

7.1 Product and price

Ginseng in USA is normally sold dried, and farmers do the drying themselves. This has changed lately, and buyers are now buying fresh ginseng rather than dried, in order to have control of root quality (Randall[29]). When sold, ginseng is mainly divided into two groups, field-grown or wild (forest-grown is sorted into either group depending on looks). The prices discussed below are dry weight and what growers can obtain in America. The most highly valued root is the wild-grown root, which attracts a much higher price than field-grown ginseng. An estimation of the prices in 2007 shows the difference; wild ginseng received 4305-8609 SEK/kg[30], while field-grown ginseng received 172-316 SEK/kg[30] (Persons and Davis, 2007). Prices have gone up, since wild ginseng now (2013) has an estimated starting price of 17218 SEK/kg[31]. In America, more and more growers are taking an interest in forest-grown ginseng. As long as the root looks similar to the wild-grown roots, the retail value is 30-70% of that of wild ginseng (Persons and Davis, 2007). According to Lewis[32], the price of forest-grown ginseng (2013) starts at 4304 SEK/kg[33].

[27] E-mail from Martin Jensen, Dept. of Food Science, Aarhus University, Denmark. 2014-05-05
[28] Interview with Henrike Rodemeier, ginseng farmer, Bockhorn, Germany. 2014-04-04
[29] Jesse A. Randall, Iowa State University, Associate Professor & Extension Forester. 2014-02-07
[30] Original figures: 300 – 600 $/pound and 12-22 $/pound. Calculation based on rate 1:6.5 (dollar: SEK).1 pound=0,453kg.
[31] Jeff Lewis, General Manager, Ginseng & Herb Coop. 2014-02-07
[32] Jeff Lewis, General Manager, Ginseng & Herb Coop. 2014-02-07
[33] Original figures: $300.00 per pound (woods grown) and $1200.00 per pound (wild).

7.2 Market

Pritts (1995) predicted that the world market would be saturated with field-grown ginseng and that it would be in the interest of new growers to focus on wild-simulated or forest-grown ginseng. According to Persons (2007), the market has been oversupplied with field-grown ginseng, making field farming difficult to survive on in the USA. However, the situation appears to have changed lately, since prices have risen significantly (Randall[34]). For a producer in Europe, it can be difficult to sell to the Asian market, since quite a large amount of ginseng is needed, so Wischmann[35] instead suggests the European market as the main option. In Denmark, the expectation is that the growers' market will be the European pharmaceuticals industry, local markets and direct sale to end consumers (Jensen, 2001).

Global ginseng production is currently about 80 000 tons, of which South Korea, China, USA and Canada produce 99%. Baeg and So (2013) expect the market to expand continuously due to increasing interest in food supplies. The form of ginseng used differs between cultures and countries, for example in South Korea 90% of the ginseng consumed is used fresh in food (Baeg and So, 2013). More than 95% of the ginseng produced in the USA is sold to China (Snow and Snow, 2009). Although America and Canada produce and export a lot of ginseng, most ginseng production occurs in Asia and almost all ginseng produced is consumed in Asia (Pritts, 1995). The USA was formerly the largest producer of field-grown ginseng, but has faced a dramatic decline because of competition from Canada, China and South Korea (Person and Davis, 2005).

Since there is a great competition for ginseng on the world market, it is important to find a high value niche market. An example of a niche market would be to sell potted plants directly to consumers, for further growth, just for their aesthetic value or for eating (Jensen, 2006). Another way to create a niche market is to focus on plant breeding with the goal of producing large roots with high concentrations of active substances, creating a qualitative advantage on the international market (Jensen, 2006). The German ginseng farm Flora Farm has created its own niche market by refining the ginseng produced and selling the products through its own pharmaceutical company (Wischman[34]).

7.3 Regulations

Ginseng in Sweden is classified as a supplement which falls under the category of food. It has to be registered with the County Administration Board as primary food production, although for this no permits are necessary and there is no fee. If the ginseng is refined, the control responsibility instead lies with the municipality (Norlin[36]). There is then a yearly fee based on a risk classification, which differs between municipalities (Helena[37]) and the responsibility lies with the producer to make sure the products are safe for customers (National Food Agency, 2014).

[33] E-mail from Jesse A. Randall, Iowa State University, Associate Professor & Extension Forester. 2014-02-07
[35] Interview with Gesine Wischmann, Flora Farm, Bockhorn, Germany. 2014-04-04
[36] E-mail from Reneé Norling, inspector county administrative board, Kristianstad, Sweden. 2014-02-10
[37] E-mail from Helena, National food agency. 2014-01-29

In Sweden, CITES regulations are administered by the Swedish Board of Agriculture and according to Gabrielsson[38], CITES permits are not needed for selling any *Panax quinquefolium* or *Panax ginseng* produced in Sweden. However, both growers and buyers need to prove the legality of their ginseng procurement.

In the EU, there are two different sets of regulations depending on whether ginseng is marketed as a supplement or an herbal medicine. When marketed as a supplement the producer is not allowed to make claims about the medical effects of ginseng, while when marketed as an herbal medicine, it may be assigned mild sickness alleviation claims. According to Jensen[39], the EU regulations may differ between countries.

While *Panax ginseng* is approved as herbal medicine in the EU, *Panax quinquefolium* is not (Jensen[40], Wischmann[40]). This means that in the EU, *Panax ginseng* can be sold and marketed as an herbal medicine, while *Panax quinquefolium* can only be marketed as a health food. This at least is the situation in Sweden. In Germany the situation is different, due to ginseng being classified as an herbal medicine (not food supply as in Sweden). Since *Panax quinquefolium* does not have herbal medicine status in the EU, it cannot be sold there. Therefore, only *Panax ginseng* can be sold in Germany (Wischmann[41]). Neither of these ginseng species is used in conventional medicines in Sweden (Burman[42]).

Panax ginseng dominates the Swedish market for ginseng supplements and products containing *Panax quinquefolium* are difficult to find. The situation in America is similar; the health food market has been dominated by products from Korea and containing *Panax ginseng*. Thus *Panax ginseng* dominates as food and as herbal medicine. Since the medicinal effects are different between the two species, there should be room for both on the European market. However, *Panax quinquefolium* is less well known and it would probably have to be introduced.

10. Discussion

The Swedish climate seems to be suitable for ginseng production. The winter temperatures could allow ginseng farming in all of Sweden, although the depth of the mulch layer needs to be adapted to provide enough protection. The risk of winter injuries in the north should be investigated to show how far north it would be meaningful to grow ginseng. In the spring, there could be a risk of spring frost, although this can be reduced, for example by protecting the emerging plants with netting. Data on the growing period and heat sum required by ginseng and the limits for the warm stratification (length of period, temperature) are not yet available and these aspects need to be researched.

Buying ginseng seeds should not be a problem since there are producers in Denmark and after the third production year Swedish growers could harvest their own seeds. However, there is the aspect of local adaptation of seeds to temperature, which would suggest that Swedish growers should try to find seeds indigenous to Canada, or adapted to colder temperatures (which perhaps includes the Danish seeds). It is very important for Swedish producers to make sure that imported seeds are

[38] E-mail Sara Gabrielsson, Swedish Board of Agriculture. 2014-03-12
[39] E-mail from Jensen, Martin, Dept. of Food Science, Aarhus University, Denmark. 2013-11-13
[40] E-mail from Jensen, Martin, Dept. of Food Science, Aarhus University, Denmark. 2013-11-04
[41] Interview with Gesine Wischmann, Flora Farm, Bockhorn, Germany. 2014-04-04
[42] E-mail from Burman, Martin, Medical Products Agency. 2013-10-21

disease-free, in order not to contaminate the location or introduce new diseases into Sweden. The transportation and storage of ginseng seeds have been somewhat difficult in America due to the perceived need for keeping the seeds moist at all times. However, Jensen (2002) showed that the seed can be kept dry until the end of the cold period, opening the way for easier transportation and storage possibilities. In America, the seeds are often stored in stratification boxes, buried in the ground for about a year to follow the seasonal temperature changes. This could perhaps be made easier for the farmer by providing a stratification centre to which the seeds could be sent. Seeds could then be retrieved in the autumn, just before planting. A stratification centre could also provide the accelerated stratification mentioned by Jensen (2001), which could make it possible to sow in the following spring after harvest.

Fungi may not be a problem at first, but the fungal pressure would probably grow with increased ginseng farming in Sweden. Other European countries have experienced this trend on introducing ginseng cultivation (Madsen *et al.*, 2001). Danish ginseng production initially showed little problems with fungi and none of the most severe diseases was detected (Madsen *et al.*, 2001). Since that study, there has been one observation of a severe fungal attack on a ginseng farm in Denmark. In Germany there are problems with fungal diseases (Henrike[43]). These fungal diseases experienced in Denmark and Germany would probably also be encountered in Sweden.

The suggested budgets for the three production systems (Tables 5-7) showed that all three are profitable at current ginseng prices and with access to the Asian market (discussed further below). The world market prices for ginseng can change radically, and this is a risk that has to be borne. In the beginning of the 1990s the price of ginseng was high, but by the beginning of the 2000s the price had fallen to about half. This has been attributed to a saturated market and increased production, but this argument can be questioned. Since the demand from China has increased and all ginseng produced is being bought, there should in fact have been a price increase. The purchasing power is increasing in both east and west, which suggests good possibilities for sales, but the selling price is difficult to predict (Madsen *et al.*, 2001).

Another factor that drastically changes the budget is the value attributed to labour. The original budgets valued labour at 70 SEK/h (Persons and Davis, 2007), while in Sweden the rate would be 182 SEK/h (Databoken, 2014). A Danish report suggests that the availability of labour at low hourly rates is good in America and that this could perhaps lower the incentive to develop more efficient production methods (Madsen *et al.*, 2001). With Swedish labour rates, there would be a high incentive to look into efficient production methods.

Sweden is rich in forests, and cultivating ginseng could be a way to increase profitability in forest production. However, since ginseng grows in deciduous hardwood forests and not so well under pine, this production would be limited to the south of Sweden. Danish research suggests that large-scale farming might be difficult in the forest due to difficulties in using bed preparation and harvesting machinery (Madsen *et al.*, 2001). The location is important for forest-grown and wild-simulated ginseng, so it would be interesting to know if there are forest soils in Sweden that have the required favourable combination of high calcium and low PH. Other plants that thrive in such conditions, so-called companion plants, should be identified in order to facilitate finding a suitable location. The existence of these in Swedish woods or whether it is possible to inoculate them in

[43] Interview with Henrike Rodemeier, ginseng farmer, Bockhorn, Germany. 2014-04-04

would have to be investigated. An interesting question is the potential of small-scale forest ginseng farmers to access the Asian market, which is probably limited unless more ginseng farms are established in Sweden so that a sufficiently large amount of product can be transported to Asia. Without access to this market, ginseng farmers are left with the European and Swedish market, where value is probably not attributed to the root due to looks, so the price premium for forest-grown ginseng might be lost. The profitability of such production would depend on the price that could be obtained in Sweden. If the selling price were to be the same as the world market price for field-grown ginseng, there would be no profit. On the other hand there might be niche markets, such as the local market, stores specializing in Asian food or the organic market where the product could receive a higher price. The same reasoning about value and market access can be applied to the wild-simulated production system.

Field-grown ginseng can be sold on world market and the European market, at the world market price. However, there are other aspects concerning the European market. One is that the fact that almost all ginseng imported to Europe is *Panax ginseng.* There might not be an interest in *Panax quinquefolium,* but only this variety could be introduced in Sweden. Another aspect is that the European drug industry might not want to confuse people with an American variety when a lot of marketing has been done for Asian ginseng (Madsen *et al*., 2001). For these reasons, the Asian market could still be an interesting option, but it would require farmers to pool their produce for sale. The estimated amount needed for sale to attract reasonable prices is 5000 kg dried root (Madsen *et al*., 2001).

It is possible to grow organic ginseng with all three production methods tested here. However, as is often the case with organic farming it might not be easy, but with a combination of creativity and research to find improvements, it can be done.

In this study, *Panax quinquefolium* was chosen for various reasons (see section 5.9), and the other variety of commercial interest, *Panax ginseng*, was not investigated further. *Panax ginseng* is a variety that could also be of interest to Sweden, since it is the type used by pharmaceutical companies today and it also has herbal medicine status, making it possible to market it differently. Flora Farm, Germany, is a ginseng producer and a pharmaceutical company and has expressed an interest in more European growers of *Panax ginseng* (Gesine[44]).

11. Conclusions

The Swedish climate seems to be suitable for ginseng farming. If large-scale ginseng production were to be initiated in Sweden, with enough farmers involved, then wild-simulated, forest-grown and field-grown production systems could all be options. With limited production, selling to the European market would make wild-simulated farming and forest ginseng farming unprofitable. The interest from the European market needs to be further investigated, and if it is low, Swedish ginseng farmer should aim to produce enough ginseng for sale to Asia (~5000 kg dried root). Access to the Asian market would also open the way for forest farming, creating increased production possibilities for Sweden and possibly adding value to hardwood deciduous forest production. Besides *Panax quinquefolium*, *Panax ginseng* could also be an interesting variety to grow in Sweden. With increasing cultivation, the fungal diseases that attack ginseng will eventually become a problem in Sweden too.

[44] Interview with Gesine Wischmann, Flora Farm, Bockhorn, Germany. 2014-04-04

Much research, experiences and alternatives to pesticides are needed in order to avoid the heavy pesticide dependence that is customary in America.

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13. Appendix

Appendix A. Extended budget information		
Wild-simulated growing under trees, 9-year growth period, 2000 m^2		
1 acre = 0.4046 ha, 1 pound = 0.453 kg, exchange rate 1 USD = 7 SEK		
Based on budget suggestion presented in "Growing and marketing ginseng, goldenseal and other woodlands medicinals" (Persons & Davis, 2007), with some alterations to Swedish conditions and present market.		
Seeds for planting 12.5 pounds (Persons & Davis 2007) 12.5 * 0.453 = 5.66 kg seeds	**Price of seeds** 80 USD/pound (Lewis[45]) 80 USD * 7 SEK = 560 SEK/pound 560 SEK/0.453 = 1236 SEK/kg	**Cost of seeds for 2000 m^2** 5.66 * 1236 SEK/kg = 6996 SEK
Labour Site preparation and planting; 25 hours (Persons & Davis, 2007) Inspection and troubleshooting; 200 hours (Persons & Davis, 2007 Digging roots; 350 h (Persons & Davis, 2007) 25 + 200 + 350 = 575 h	**Wages** 182 SEK/h (Databoken, 2014) Recommended wages for a 19-year-old with one year of farming experience.	**Cost for labour** 575 h * 182 SEK/h = 104650 SEK
Tools Rake, pulaski (special axe), digging tool, assume some equipment already at hand. Estimated to 50 USD (Persons 2007).		**Cost for tools** 50 * 7 = 350 SEK
Backpack sprayer, disease and pest control 300 USD (Persons and Davis, 2007)		**Cost of backpack sprayer etc.** 300 * 7 = 2100 SEK
Drying room Insulation and equipment to adapt an existing room to drying. Estimated to 400 USD (Persons & Davis, 2007).		**Cost of drying room** 400 * 7 = 2800 SEK
Energy for drying 0.5 USD/pound dried root as estimated by Persons & Davis (2007)	**Energy price** 0.5 USD *7 = 3.5 SEK/pound= 3.5/0.453 = 7.73 SEK/kg	**Cost of energy** 7.73 SEK * 36 kg dried root = 278 SEK
Expected amount of root harvested 80 pounds dried root (Persons & Davis 2007) 80 * 0.453 = 36 kg	**Root price** 350 USD/pound (Persons & Davis 2007) 350 * 7 = 2450 SEK/pound 2450/0.453 = 5408 SEK/kg	**Income from root** 5408 SEK/kg * 36 kg = 194688 SEK
Income - costs Costs = 6996 + 104650 + 350 +2 100 + 2800 + 278 = 117174 Income = 194688 SEK		**Net profit after 9 years** 194688 - 117174 = 77514 SEK

[45] E-mail from Jeff Lewis, general manager at Ginseng & Herb Cooperative, Wisconsin USA. 2014-02-07

Appendix B. Extended budget information		
Cultivation under trees, 6 year growth period, 2000 m2		
1 acre = 0.4046 ha, 1 pound = 0.453 kg, exchange rate 1 USD = 7 SEK		
Seeds for sowing 24 pounds (Persons & Davis 2007) 24 *0.453 = 10.9 kg seeds	**Price of seeds** 80 USD /pound (Lewis[46]) 80 USD * 7 SEK = 560 SEK/pound 560 kr /0.453 = 1236 SEK/kg	**Cost of seeds for 2000 m^2** 10.9 * 1236 SEK/kg = 13472 kr
Fungicides, herbicides, fertilizer, gas, oil 1000 USD (Persons & Davis, 2007)		**Cost of fungicides etc** 1000 *7 =7000 SEK
Tiller bought Rear tined tiller, tilling capacity 60 cm	**Price tiller** 10400 (Nima maskinteknik AB)	**Cost tiller** 10 400 SEK
labour Site preparation and planting; 300 hours (Persons & Davis, 2007) Care and maintenance 1000 hours (Persons & Davis, 2007 Harvest, seed and roots; 650 hours (Persons & Davis, 2007) 300 + 1000 + 650 =1950 hours	**Wages** 182 SEK/h (Databoken, 2014) Recomended wages for a 19-year-old with one year of farming experience.	**Cost for labour** 1950 hours * 182 SEK/h = 354900 SEK
Garden seeder 75 USD (Persons & Davis, 2007)		**Cost of gardenseeder** 75 * 7 = 525 SEK
backpacksprayers 2*125 USD (Persons & Davis, 2007)		**Cost of backpacksprayers** 250 * 7 = 1750 SEK
Drying room; insulation etc 600 USD (Persons & Davis, 2007)		600 * 7 = 4200 SEK
Energy for drying 0.5 USD/pound dried root as estimated by Persons & Davis (2007)	**Energy price** 0.5 USD *7 = 3.5 SEK/pound= 3.5/0,453 =7.73 SEK/kg	**Cost of energy** 7.73 SEK*136 kg dried root = 1051 SEK
Amount root harvested 300 pounds dried root (Persons & Davis 2007) 300 * 0.453 = 136 kg	**Root price** Price estimation by Lewis[2] ; prices start at 300.00 USD per pound and goes up. Value of 300.00 USD has been used. 300 * 7 = 2100 SEK/pound 2100/0.453 = 4636 SEK/kg	**Income from root** 4636 SEK/ kg * 136 kg = 630496
Income - costs Costs = 13472 + 7000 + 10400 + 354900 + 525 + 1750 + 4200 + 1051 = 393 298 Income = 630 496		**Net profit** 630496 - 393298 = 237 198

[46] E-mail from Jeff Lewis, general manager Ginseng & Herb Cooperative, Wisconsin USA. 2014-02-07

Appendix C. Extended budget information **Field cultivation small scale, 4 year growth period, 400 m^2**		
1 acre = 0.4046 ha, 1 pound = 0.453 kg, exchange rate 1 USD = 7 SEK		
Amount of Seeds for sowing 80 pounds/acre (Persons & Davis 2007) 80*0.453 kg/0.4046 ha = 89.57 kg/ha 400 m^2 =0.04 ha 0.04*89.57 = 3.6 kg seeds	**Price of seeds** 80 USD /pound (Lewis[47]) 80 USD * 7 SEK = 560 SEK/pound 560 SEK/0.453 = 1236 SEK/kg	**Cost of seeds for 400 m^2** 3.6 kg * 1236 SEK/kg = 4450 SEK
Mulch Straw mulch		**Cost of mulch for 400 m^2** 40 USD (Persons & Davis, 2007) 40 *7 = 280 SEK
Labour 400 hours (Persons and Davis, 2007) (all work during 4 years including seeding, harvest and drying)	**Wages** 182 SEK/h (Databoken, 2014) Recommended wages for a 19-year-old with one year of farming experience.	**Cost for labour** 182 SEK/h * 400 h = 72800 SEK
Tiller Assuming tiller is rented. Assuming tilling speed 100 m @ 10 min, 60 cm wide tilling capacity and tilling the area 3 times before sowing.	**Price of tiller** Rental cost 450 SEK/day (CS Maskin AB). 11 beds (1.2 m wide). Each bed 20 m long. 2 * 11= 22 walks* 20 m/tilling occasion = 440 m. 440m/ (10 m/min) = 44 min. Tilling at 3 different occasions.	**Cost of tiller rental** Rental time totally 3 days 405 SEK* 3 days = 1215 SEK
Fungicide sprayer 100 USD (Persons & Davis 2007)		**Cost of fungicide sprayer** 100 USD *7 = 700 SEK
Energy for drying 0.5 USD /pound dried root as estimated Persons and Davis (2007)	**Energy price** 0.5 USD *7 = 3.5 SEK/pound= 3.5/0.453 =7.73 SEK/kg	**Cost of energy** 7.73 SEK*90 kg dried root = 696 SEK
Shadeconstruction		**Cost of shade construction** 1230 USD (Persons & Davis, 2007) 1230 * 7 = 8610 SEK
Fungicides/pesticides 45 USD (Persons & Davis, 2007)		**Cost of fungicides/pesticides** 45 * 7 = 315 SEK
Amount seed harvested 20 pounds/year (Persons & Davis, 2007) 20 *0.453 = 9 kg/year * 2 years of harvest = 18 kg seed	**Seed price** 80 USD/pound (Lewis[30]) 80 USD * 7 SEK = 560 SEK/pound 560 SEK/0.453 = 1236 SEK /kg	**Income from seed** 1236 SEK/kg * 18 kg = 22 248 SEK
Amount root harvested 200 pounds dried root (Persons & Davis 2007) 200 * 0.453 = 90 kg	**Root price** From 75 USD to 95 USD per pound (Lewis[30]). Calculated value 85 USD/pound. 85 * 7 = 595 SEK/pound 595/0.453 = 1313 SEK/kg	**Income from root** 1313 SEK/kg (Lewis[3])*90 kg 1313 SEK/kg * 90 kg = 118170 SEK
Income - costs Costs = 4450 + 280 + 72800 + 1215 + 700 + 696 + 8610 +315 = 89066		**Net profit** 140418 - 89066 = 51352
Income = 22 248 + 118170 = 140418		

[47] E-mail from Jeff Lewis, general manager at Ginseng & Herb Cooperative, Wisconsin USA. 2014-02-07