Natural resources and
bioeconomy
studies 88/2017

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Luke
NATURAL RESOURCES
INSTITUTE FINLAND

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Natural Resources Institute Finland, Helsinki 2017

Ruotsalainen, S. 2017. The history of cultivation of exotic tree species in Finland. Natural resources and bioeconomy studies 88/2017. Natural Resources Institute Finland, Helsinki. 27 p.

ISBN: 978-952-326-525-7 (Print)
ISBN: 978-952-326-526-4 (Online)
ISSN 2342-7647 (Print)
ISSN 2342-7639 (Online)
URN: http://urn.fi/URN:ISBN:978-952-326-526-4

Author: Seppo Ruotsalainen
Publisher: Natural Resources Institute Finland (Luke), Helsinki 2017
Year of publication: 2017
Cover photo: Teijo Nikkanen
Printing house and publishing sales: Juvenes Print, http://luke.juvenesprint.fi

Summary

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The cultivation of exotic tree species in Finland started presumably already in the Middle Ages, with introduction of fruit trees to Finland. During the period of the Enlightenment in the 18th century an intensive period of introduction started in the Academy of Turku, but this contributed very little permanent results.

From the forestry point of view the cultivation of exotics in Finland has two different historical roots. The first of them is the establishing of the Raivola larch stand in the 18th century and the second the start of state forest administration and forest education in 1860's. The early introductions were often unplanned and the success of them was usually poor, as the importance of the origin was not well understood or hardy enough material was not available. More systematic work with the exotics started in the 20th century by Arboretum Mustila and the Finnish Forest Research Institute, which also have recognised the importance of the geographic origin of the introduced species. Several areas have been identified around the world with a climate close enough to that of Finland, so that they have high probability for providing species adapted to Finnish conditions.

In the late 19th century Russian species were dominant among the exotics cultivated for forestry purposes. In addition to Siberian larch (*Larix sibirica*) also Siberian stone pine (*Pinus cembra* subsp. *sibirica*) and Siberian fir (*Abies sibirica*) were grown in Finland. European larch (*L. decidua*) was also cultivated to some extent. Later on the number of the tested species has greatly increased, but only a few exotic species have shown any usability in Finnish conditions. Of the exotics currently only Siberian larch and lodgepole pine (*Pinus contorta* var. *latifolia*) have some practical importance in Finnish forestry, but their combined share of the forests is only 0.1%.

In the near future only Siberian larch will have some practical use in Finnish forestry. With a longer perspective cultivating exotics should be encouraged, because they can be regarded as insurance for changing climatic and economic conditions, which may require new species or commodities. Collecting experiences and maintaining cultivation tradition of the exotics can prove valuable in the changed conditions.

Keywords: assisted migration, climatic adaptation, exotics, geographic origin, *Larix sibirica*

Yhteenveto

Vieraiden puulajien viljely alkoi Suomessa todennäköisesti jo keskiajalla, jolloin Suomeen tuotiin ensimmäiset hedelmäpuut. Valistuksen aikakaudella 1700-luvulla Turun Akatemia aloitti intensiivisen vieraiden puulajien viljelyn, mutta näistä kokeiluista jäi hyvin vähän pysyviä tuloksia.

Vieraiden puulajien metsätaloudellisella viljelyllä Suomessa on kaksi eri historiallista lähtökohtaa. Ensimmäinen niistä on Raivolan lehtikuusikon perustaminen 1700-luvulla, ja toinen valtion metsähallinnon ja metsäopetuksen järjestäminen 1860-luvulla. Varhaisimmat viljely-yritykset olivat usein suunnittelemattomia ja niiden menestys oli yleensä huono. Syynä tähän oli, että alkuperän merkitystä ei ymmärretty riittävän hyvin eikä tarpeeksi kestävää materiaalia ollut saatavilla. Järjestelmällisempi työ vieraspuulajeilla alkoi 1900-luvulla, kun Mustilan Arboretum ja Metsäntutkimuslaitos aloittivat toimintansa. Ne ottivat työssään huomioon myös vierasperäisten lajien maantieteellisen alkuperän. Eri puolilta maailmaa on tunnistettu useita maantieteellisiä alueita, joiden ilmasto muistuttaa niin paljon Suomen ilmastoa, että niiltä todennäköisesti on saatavissa myös Suomessa käyttökelpoisia puulajeja.

Venäläiset puulajit olivat 1800-luvun lopulla Suomessa runsaimmin viljeltyjä vieraita puulajeja. Siperianlehtikuusen (*Larix sibirica*) lisäksi Suomessa kasvatettiin myös siperiansembraa (*Pinus cembra* subsp. *sibirica*) ja siperianpihtaa (*Abies sibirica*). Myös euroopanlehtikuusta (*L. decidua*) kasvatettiin jossain määrin. Myöhemmin testattujen lajien määrä on lisääntynyt huomattavasti, mutta vain harvat vierasperäiset lajit ovat osoittautuneet käyttökelpoisiksi Suomen olosuhteissa. Ainoastaan siperianlehtikuusella ja kontortamännyllä (*Pinus contorta* var. *latifolia*) on jotain käytännön merkitystä Suomen metsätaloudessa, mutta niidenkin yhteinen osuus metsistä on vain 0,1 %.

Lähitulevaisuudessa vieraista puulajeista vain siperianlehtikuusella on jotain metsätaloudellista käyttöä Suomessa. Pidemmällä aikavälillä vieraiden puulajien viljelyä olisi kannustettava, koska niitä voidaan pitää vakuutuksena muuttuvien ilmastollisten ja taloudellisten olosuhteiden varalta. Uusissa oloissa saatetaan tarvita uusia lajeja ja tuotteita. Keräämällä viljelykokemuksia vieraista puulajeista ja ylläpitämällä viljelyperinteitä voidaan varautua muuttuviin olosuhteisiin.

Asiasanat: avustettu levittäytyminen, ilmastoon sopeutuminen, vierasperäiset lajit, maantieteellinen alkuperä, *Larix sibirica*

Contents

1. Introduction

People have been shaping their environment already for thousands of years, for example by transferring tree species to new environments. During the antiquity e.g. cypress (*Cupressus sempervirens*) and olive tree (*Olea europaea*) were dispersed throughout the Mediterranean area by man, so that the original distribution areas of them are greatly enlarged and partly unknown (Ilvessalo 1916, Sarvas 1964, Hagman 2008). The Romans were especially effective in spreading trees to their newly conquered areas. In this way for instance walnut (*Juglans regia*) and chestnut tree (*Castanea sativa*) were introduced to Central Europe and even to England (Cajander 1917).

According to Cajander (1917) there are several reasons for introducing tree species, but the following three are the most important from the forestry point of view. First, the introduced species may have a higher wood production capacity compared to the native ones. Second, it may hold some silvicultural advantage over the native species, like better resistance to adverse environmental factors or damaging agents. Third, the introduced species may have some special wood qualities or produce some specific commodities which native species are missing.

The introduction of exotic tree species in Finland followed developments at the more southern latitudes in Europe, but with a considerable delay and with poorly documented beginning. The first introductions were fruit trees (apple (*Malus domestica*), pear (*Pyrus communis*), plum (*Prunus domestica*), cherry (*Prunus avium*)) probably already in the Middle Ages, the first written records dating to 16th century (Oja 2008). In 1539 the owner of Suitia estate in southern Finland, Erik Fleming, ordered apple and pear trees for his garden from Tallinn, Estonia (Häyrynen 2008). Chestnut (*Castanea*) appears already on the plant list of southwestern Finland from the year 1683 (Tillandz 1683), but it can also point to horse chestnut (*Aesculus hippocastanum*) (Häyrynen 2008), because the nomenclature was not established at the end of 17th century. This is the only exotic tree species on that list in addition to the fruit trees.

The current number of native woody species is low in Finland, some 90 species of trees and shrubs, four of them conifers (Hämet-Ahti 2008). Only four of the native tree species (Norway spruce (*Picea abies*), Scots pine (*Pinus sylvestris*), silver birch (*Betula pendula*), downy birch (*B. pubescens*)) are of noteworthy economic significance. Thus it can be expected that there are both silvicultural and economic niches for exotic tree species in Finnish forestry. Further, the number of tree species was clearly higher in this area before the latest glaciations. In geological surveys in Finnish Lapland pollen of larch (*Larix*), fir *(Abies*) and hemlock (*Tsuga*) have been discovered in peat deposits more than 100 000 years old, all representing genera foreign to current Finland or even the whole of Europe (Hirvas 1991).

This article reviews the history of the introduction of exotic trees to Finland. The reasons for and results of these efforts are described. Although currently the use of exotic tree species is of rather low importance in Finnish forestry, the situation may change in the future. If the climatic change is in the line of the worst scenarios, the new climatic situation may require new genetic adaptations for optimized utilisation of the growing conditions. This can be obtained by transferring new genotypes, either provenances of the existing species or new species to the area, an old method currently marketed as assisted migration (e.g. Winder et al. 2011). Therefore it can be useful to know the history in order to learn from the past successes and failures. Most of the time period discussed belongs to an era when Finland as a sovereign state did not exist, and also during its independence the territory of Finland has had different boundaries. These obscurities are solved with a rather inclusive approach, so that all cultivations which according to any definition can be considered as Finnish, are discussed. For the localities the Swedish names are also given if they exist, because the older literature is mainly using them. For the nomenclature of the species Farjon (1990) and Hämet-Ahti et al. (1992) are followed. This has importance especially in case of larches, so that all larches in western Russia are classified as *Larix sibirica*, whereas especially in the Russian literature the westernmost larches are separated to another species with name *L. sukaczewii*. However, with the oldest historical sources the validity of the used names cannot be guaranteed.

2. New species for the best of the nation

Intensive period of experimenting with exotic tree species in the 18th century was boosted by an increased interest in utilising natural resources. This was caused by the political and economic situation in Sweden, to which main part of Finland belonged at that time. Sweden had lost the war against Russia and the southeastern part of Finland was annexed to Russia in the treaty of Uusikaupunki (Nystad) in 1721.The economy of the state was ruined during the war and state budget was on deficit. Therefore it was natural that a mercantilist interest for more intensive use of the own natural resources arouse as a means of replacing imported products (Oja 2008). In the spirit of the Enlightenment universities were harnessed for this task, and in the eastern part of the kingdom the central actor in these activities was the Royal Academy of Turku (Åbo).

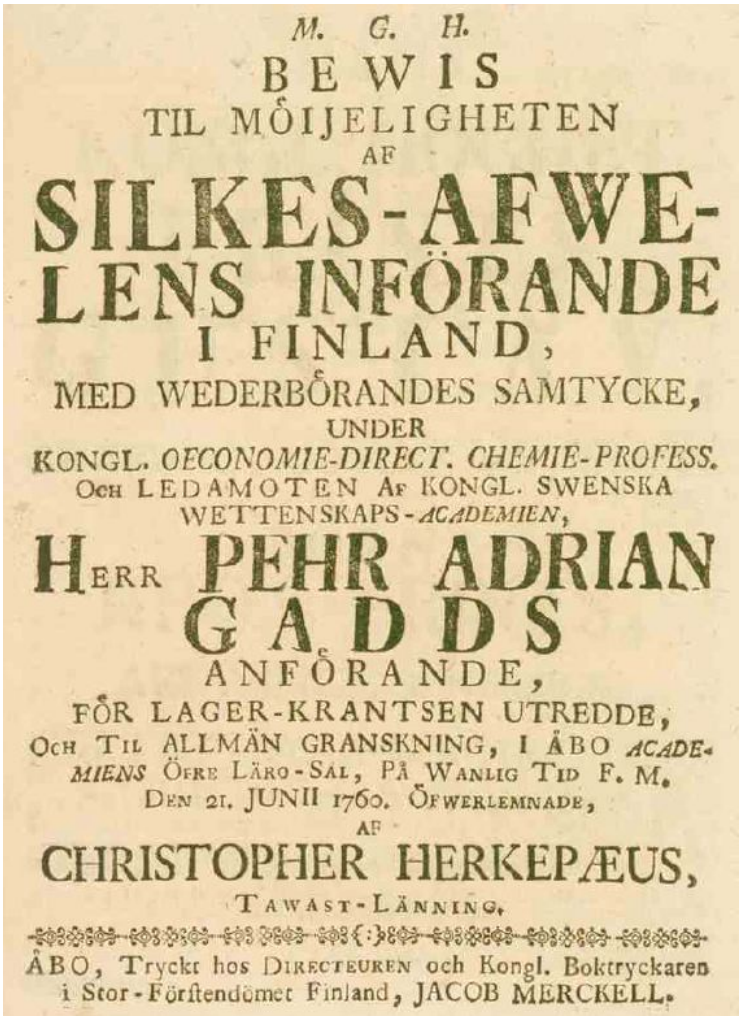
There were two remarkable men in the Academy of Turku who worked with introduction of exotic tree species and studied their cultivation in Finland. Pehr Kalm, professor of economics, made several expeditions to different countries and studied both introduced and native plants (Hjelt 1896). His contemporary and bitter rival, professor of chemistry, Pehr Gadd, was nominated as a "planting director" of Finland with an order to establish experiments with exotic species, to teach people in gardening and to deliver seeds (Oja 2008).

The most important of the expeditions which Pehr Kalm made was that to the east coast of North America in 1749–1751, which was supported by his previous teacher Carl von Linné. The purpose of the trip was to get economically important plants from there (Hjelt 1896). Woody plants were well represented among the seeds which he procured during his journey. Ilvessalo (1916) lists 11 conifers (e.g. *Abies balsamea*, *Larix laricina*, *Picea mariana*, *Pinus taeda*) and 16 broadleaved trees (e.g. *Acer rubrum*, *Juglans nigra*, *Robinia pseudoacacia*) as a catch from this expedition.

Pehr Kalm established plantings with exotic plants on the estate Sipsalo, in the vicinity of Turku, which was allocated for this purpose, but also in the botanical garden of the Academy. The species which he tested were mainly his acquirements from North America, but it is not easy to find out exactly which of those seeds he brought from his journey were cultivated in Turku. Kalm mentions in his report in 1759 by name about 20 North American woody species growing his gardens, but refers to many others which he does not discuss (Kalm 1888). Of these species only about five are the same as mentioned by Ilvessalo (1916) (the uncertainty is caused by obscurities in the used names). These common species are *Juniperus virginiana*, *Acer saccharum*, *Juglans nigra*, *Tilia americana* and possibly *Carpinus caroliniana*.

Other North American species, which Kalm cultivated in Turku were e.g. mulberry tree (*Morus rubra*) and a species of hawthorn (*Crataegus coccinea*), black spruce (*Picea mariana*) and eastern white pine (*Pinus strobus*) (Hjelt 1896, Kukkonen 1979). From the list of species, and especially from those discussed most, it can be deduced, that increasing wood production was not of the main interest, but some special purposes like hard wood for tools (*Carpinus caroliniana*) or hedges to replace wooden fences and thus saving forests (*Crataegus coccinea*). Eurasian exotics cultivated by Kalm were e. g. *Carpinus betulus*, *Morus alba* and "Siberian juniper and pine" (Hjelt 1896).

One of the most innovative enterprises during that era was the effort to start silk production in the kingdom of Sweden, Finland included. Silk production in Finland was especially keenly studied by Pehr Gadd (Fig. 1). Producing silk required growing of mulberry trees (*Morus* sp.) for feeding the silkworms, and in fact one of the aims of the Kalm's expedition to North America was to find a more climate tolerant species of mulberry tree than the European *Morus alba*, which did not give satisfactory results. Finally, after more than ten years continued studies Gadd had to admit, that silk production was not feasible in Finland, mainly due to lacking climatic tolerance of the mulberry trees, the silkworms were not the weak link (Johansson Åbonde 2010).



M. G. H.

BEWIS
TIL MÖIJELIGHETEN
AF
SILKES-AFWE-
LENS INFÖRANDE
I FINLAND,
MED WEDERBÖRANDES SAMTYCKE,
UNDER
KONGL. OECONOMIE-DIRECT. CHEMIE-PROFESS.
OCH LEDAMOTEN AF KONGL. SWENSKA
WETTENSKAPS-ACADEMIEN,
HERR PEHR ADRIAN
GADDS
ANFÖRANDE,
FÖR LAGER-KRANTSEN UTREDDE,
OCH TIL ALLMÄN GRANSKNING, I ÅBO ACADE-
MIENS ÖFRE LÄRO-SAL, PÅ WANLIG TID F. M.
DEN 21. JUNII 1760. ÖFWERLEMNADE,
AF
CHRISTOPHER HERKEPÆUS,
TAWAST-LÄNNING.

ÅBO, Tryckt hos DIRECTEUREN och Kongl. Boktryckaren
i Stor-Förstendömet Finland, JACOB MERCKELL.

Figure 1. Cover page of an academic dissertation discussing the possibilities of silk production in Finland. The dissertation was done in the Academy of Turku under the supervision of Pehr Gadd in 1760 (Gadd & Herkepaeus 1760).

The great expectations put on cultivating the exotic tree species remained unfilled and gradually interest vanished and attitudes turned to the opposite, so that finally in the parliamentary session in 1772 all cultivation grants were abolished and it was imposed a fine for them who tried to get continued financing for cultivation experiments (Hjelt 1896). There are several reasons for the failures in the introductions. The expectations as such were highly unrealistic, which prefaced for disappointment. The main site used for cultivating the plants, the Sipsalo estate, was not especially suitable for growing exotic species due to its heavy clay soil (Ilvessalo 1916). At that time the importance of climatic adaptation was not well understood, as can also be seen from the examples of the introduced species given above. By current standards Kalm was not able to get hardy enough origins from the area he visited (New England and southeastern Canada) for those species which currently can be excellently grown in Finland. Probably the final hit was the cold winter 1759-60 which also killed many of the more tolerant species (Ilvessalo 1916). Interest for taking care of the remaining cultivations decreased so that due to mismanagement they gradually perished, not leaving any permanent mark on Finnish forestry. As ornamental woody plants only the above mentioned hawthorn (*Crataegus coccinea*) and flowering raspberry (*Rubus odoratus*) are believed to originate from Kalm's introductions from North America (Kukkonen 1979).

With hindsight it is easy to see the weaknesses in the plans of introduction, or better a lack thereof. One contributing factor for the overoptimistic expectations was the favourable climate in the middle of the 18th century, which made people to believe that climate had been permanently improved by human activities like draining of peatlands and clearing of forests (Oja 2008). As already earlier mentioned, in the 18th century the idea of climatic adaptation of the trees was not as well established as nowadays. Some idea about adaptation existed, however, as can be seen from the comparisons between the climates of Finland and some of the native growing sites of mulberry made by Gadd (Johansson Åbonde 2010). The fact that the agricultural crop plants and domestic animals originated from milder climates was also used as an evidence for the possibility of cultivating trees in colder climates than their native (Ilvessalo 1920, Johansson Åbonde 2010). The practical difficulties in obtaining hardy enough seed sources were compensated by overestimating adaptation – or as it was expressed - acclimatisation capacity of the southern trees to northern climate.

3. Early gardening

Manor houses and parsonages were important promoters for cultivation of exotic trees in Finland in the late 18th and early 19th century. In the beginning fruit trees and ornamental bushes like roses (*Rosa* sp.), hawthorn (*Crataegus* sp.) and Siberian peashrub (*Caragana arborescens*) were the dominating woody exotics, reflecting the influence of the Academy of Turku. In late 18th century the English landscape parks became fashionable inducing the use of exotic conifers. The cultivation of European and Siberian larch (*Larix decidua* and *L. sibirica*), Siberian stone pine (*Pinus cembra* ssp. *sibirica*), balsam fir (*Abies balsamea*) and eastern arborvitae (*Thuja occidentalis*) in Finland presumably started at that time (Häyrynen 2008).

In the early 19th century planting of trees became more popular also among the bourgeoisie and associations promoting the planting of trees were founded. Fruit trees and native noble hardwoods (linden (*Tilia cordata*), oak (*Quercus robur*) etc.) were the most popular trees being planted, but also some exotics (e.g. *Populus alba*, *Aesculus hippocastanum*, *Pinus strobus*, *Pinus nigra*) were used (Nummi 2008). Following the growing interest in trees, nurseries and seed companies appeared to respond the growing demand for planting stock. The Finnish nurseries could not, however, fulfill the needs of the market, so there was also much import from Estonia, Sweden and other countries. This was facilitated by the fact that many of the professional gardeners in Finnish manor houses and towns were immigrants, who had good contacts to their country of origin (Nummi 2008).

In the second half of the 19th century the interest for gardening increased in Finland and the number of available species grew. A new important actor in spreading planting activity appeared when the railway network started to spread throughout Finland, and ornamental plantings were done in the vicinity of the railway stations. These plantings served as models as well as sources of inspiration for people in different parts of the country. At the same time they also formed a large experimental network. A prominent person in this development was the stationmaster of the railway station in Viipuri (Vyborg) Gustaf Niklander, who had a personal interest in gardening. In addition to planning and carrying out plantings along the railways, he established a park, a nursery and gardening shop in Viipuri (Nummi 2008). He was also active in experimenting with the material sold from his nursery and spread his experiences through presentations and publications (e.g. Niklander 1892). There really was a need for experimenting, since the seed catalogues offered far too susceptible plants for the people to grow, like the tropical ebony (*Diospyros*) (Nummi 2008). By the end of the 19th century cultivating exotic trees had spread all over Finland, so that Siberian larch and Siberian fir (*Abies sibirica*) were growing even in Inari (Enare) at latitude of 69 °N (Parvela 1928).

4. Exotics for forestry

The use of exotic trees in forestry took a decisive step forward in 1859 when the management of the state forests was organized and one of the responsibilities for the new Forest Service became establishing "model parks" where exotic tree species should be introduced. The implementation of this task was not very efficient, but the order showed keen interest of the responsible authorities for increasing the production of the Finnish forests, which were severely devastated by slash and burn cultivation (Ilvessalo 1916). This can be regarded as broad-minded, because at that time in Germany, from where Finland got much of its forestry influences, cultivation of the exotic trees was not fashionable. The Finnish positive attitude towards use of exotic tree species can possibly be attributed to two men who already in 1840's advocated for cultivating larch (Leikola 2008). One of them was land surveyor Georg Henrik von Fieandt, who published a forestry textbook in 1848, in which he warmly recommended cultivation of larch. Another supporter of growing larch was a sawmill owner and industrialist Nils Ludvig Arppe, who not only advocated for larch, but also established in 1843 a 12 ha large plantation with larches (*Larix decidua* and *L. sibirica*) in Kitee (Kides) in Eastern Finland (Cajander 1917).

When forestry education in Finland started through the establishment of the forestry institute in Evo (Evois) in 1861, it was immediately harnessed for the introduction task of exotic tree species given to Forest Service. The man who took responsibility of the cultivation was the teacher and later principal of the Evo Forestry Institute Anton Gabriel Blomqvist, who started the work mainly with larches (Huuskonen et al. 2008). The first plantings were done with European larch, but later Blomqvist favoured the Siberian larch. This was inspired by his "rediscovery" of the magnificent Raivola larch stand in 1869 (see a more detailed description of Raivola below). Other species commonly planted (Siberian stone pine, Siberian fir) also came from Russia, which has a natural explanation in the fact that Finland belonged to the Russian empire at that time. There was a special aim in promoting the cultivation of Siberian stone pine in Finland, because it was hoped that its large seeds could be used as substitute food if cereal crops failed ("bread pine"). Thus Evo obtained its first seeds of this species in 1869, after the fateful famine years 1867 – 1868, in order to start cultivation experiments with it (Ilvessalo 1913). From the 1880's onwards, cultivation experiments included a wider geographic selection covering species from North America, Balkan, Caucasus and East Asia (Ilvessalo 1920).

The cultivation of exotic tree species started in the state forests close to Evo, but later on experimentation spread to other areas too, of which Punkaharju is the most notable (Cajander 1917). The cultivation of exotics started there with Siberian larch in 1877 and continued with European larch and many other species (Fig. 2). The nursery of Evo was selling seedlings of both native and exotic tree species to state forests, different kind of institutions and private persons throughout Finland (Huuskonen et al. 2008). At the end of the 19th century small scale practical plantations were established in state forests also in Lapland. In some cases the work was financed by the local foresters, which indicates their enthusiasm for the exotics (Reuter 1918). Also other forestry schools took cultivation of exotics in their programmes and exotic conifers are still characteristic to the surroundings of the schools (Fig. 3).

Figure 2. A stand of European larch in Punkaharju, southeastern Finland, planted in 1880. The volume of the growing stock was at the age of 122 years 800 m^3/ha and dominant height 38 m. Photo T. Nikkanen.

In the beginning the cultivations were often made on areas used for slash and burn agriculture, sometimes the seeds of the trees were even sown together with the cereal crops. In the beginning the cultivations were established as mixtures with native species or using several exotics together. The use of mixed plantations was inspired both by Blomqvist's own observations in the native larch forests in Russia and by the ideology of mixed forests, which was strongly advocated by a renowned German forester Karl Gayer (Ilvessalo 1913, Huuskonen et al. 2008). A record in this respect was one stand close to Evo, which consisted of nine different tree species, seven of which were exotics. This method usually resulted in poor outcome for the exotics, so it was abandoned in the 1890's. In addition to improper silvicultural methods many larch plantations (especially those of Siberian larch) suffered from attacks by aphids (*Chermes abietis*) (Ilvessalo 1916).

Figure 3. A row of Siberian firs at Tuomarniemi forestry school. Photo T. Tasanen.

The survey of cultivation of exotic trees in Finland by Ilvessalo (1920) sums up the experiences of these early efforts with exotic trees. He listed about 80 coniferous and 20 broadleaved exotic species having been grown in Finland. Of the conifers 12 species were regarded as fairly common, mostly species from Europe or eastern North America. It is interesting to note that the only common species from western North America were *Abies concolor*, *Picea engelmannii* and *P. pungens*, which all have some ornamental value due to their bluish needles. This illustrates well that silvicultural values had not been dominating in the cultivation experiments.

In his survey Ilvessalo (1920) stated that considering the relatively long time since the start of professional work with exotic tree species in Finland and wide distribution of exotic cultivations throughout the country, the obtained results were rather meagre. According to him this was caused by poor planning and lack of orderliness, exactness and professionalism in the work. The situation

was rather similar also in other European countries. There usually was enough enthusiasm, at least in the beginning, but with continued misfortunes also this was often waning. One of the few positive exceptions was a private land owner, A. F. Tigerstedt, who had started a large scale systematic work for establishing an arboretum on his estate Mustila in southeastern Finland in 1901 (Cajander 1917). Mustila arboretum is renowned for its experiments with lodgepole pine (*Pinus contorta* var. *latifolia*) and Douglas-fir *(Pseudotsuga menziesii*) (Fig. 4).

Figure 4. A hundred years old Douglas-fir at the Mustila arboretum in October 2015. The breast height diameter of the tree is 108 cm and height 38 m. Under the tree are standing Jukka Lehtonen (left) and Esko Oksa from Natural Resources Institute Finland. Photo T. Nikkanen

5. The Raivola larch stand

The Raivola larch stand was established in 1738 for the needs of the growing Russian navy, but it has never been used for that purpose. The first cultivation was done under the guidance of a German forester Ferdinand Gabriel Fockel. The establishing history of the stand was described by Fockel himself in his book in 1766, but its later phases during the next hundred years are mainly documented in administrative archives (Redko & Mälkönen 2001). The first cultivation was done by sowing an area of about two hectares with larch seeds from Archangelsk area, some 700 km northeast from Raivola. Later on the cultivation was expanded by planting so that finally the area of pure larch stands covered about 20 hectares (Redko & Mälkönen 2001).

The Raivola larch stand has an international background; it was established by the order of Russians under the guidance of a German forester on a place belonging to the historical Finland (at that time already detached from the kingdom of Sweden and annexed to the Russian empire). For more than a hundred years it also belonged to the politically defined Finland, first to the grand duchy and then to the independent country. Since the last border change after the Second World War Raivola has belonged to Soviet Union and currently to Russia. The variants of the name for the stand reflect also its long history and multicultural status. The Russian foresters call it Lintula larch forest (Линдуловская лиственничная роща) according to the Lintulanjoki river on the banks of which it is growing. In the earliest Finnish documents it is known as Uusikirkko (Nykyrka) larch stand after the municipality where it is located, but later on its Finnish name was established as Raivola due to the nearby railway station (Ilvessalo 1923).

The Raivola larch stand was known in Finland already in the earlier part of the 19th century as is shown by the fact, that its seed was used to establish the Kitee larch stand in 1843 (Blomqvist 1893) and it was mentioned in some forestry books, too. Its existence was also known at the Evo Forestry Institute in 1863, because its principal had tried to obtain seed from Raivola for cultivations (Ilvessalo 1916). However, its importance was really understood only after it was visited by A. G. Blomqvist in 1869. When he saw the stand for the first time, he was amazed by the straight and nice trunks of the larches. At that time the forest was unknown to the Russian forestry authorities and scientists in St. Petersburg, and Blomqvist had difficulties to convince them that the species really was Siberian larch, not the European larch (Blomqvist 1893).

Not only the quality of the trees in Raivola was impressive, but also the size of them (Fig. 5). In at that time 110 years old stand Blomqvist measured a standing volume of 626 m^3/ha and the tallest tree was 40 metres tall (Redko & Mälkönen 2001). Blomqvist described the forest being the most beautiful in whole Finland, and wrote that he had never seen a better larch stand in Russia either (Blomqvist 1893). No wonder, that this stand inspired Finnish foresters to cultivate Siberian larch. It also quite concretely served as a source of forest regeneration material to the new cultivations. After its “rediscovery” the Raivola larch stand was visited and studied intensively both by Finnish and Russian foresters, as well as also by some foreign scientists, most prominent among them the German professor Heinrich Mayr in 1899 (Mayr 1900). During the years when it belonged to independent Finland (1917–1944) it was studied by many Finnish forest scientists, the most detailed study being that of Ilvessalo (1923).

Figure 5. The oldest part of Raivola larch forest (sown in 1738) photographed in 1920 (left) and 1994 (right). Photos from Forest Research Institute photo archive, Natural Resources Institute Finland, L. Ilvessalo (1920) and E. Oksanen (1994).

The oldest cultivations in Raivola (1738–1750) were made using seeds obtained from Archangelsk, although the exact location is not known. It is likely that the seeds originated some 200 km south of the town Archangelsk, by the river Dvina (63 °N) (Redko & Mälkönen 2001). The origin of the second phase of cultivation (1772–73), which forms the greatest part of the Raivola stand, is much disputed. Some authors claim that the seeds were coming from Ufa at clearly more southern latitude (55 °N) in the Ural mountains (Mayr 1900, Metzger 1935, Sarvas 1964, Tigerstedt et al. 1983), whereas according to others it is unknown (Redko & Mälkönen 2001). In fact the good growth and high adaptability of the Raivola seed source has been attributed partly to it consisting of hybridisation between northern Archangelsk and southern Ufa origins (Tigerstedt et al. 1983, Vakkari et al. 1995). However, a current review based on a number of studies on growth rhythm and adaptive characteristics of Raivola seed source and its putative ancestral origins reveals that the Raivola larches behave much alike the larches from Archangelsk (Ruotsalainen 2018). Thus at least the most extreme claims of Metzger (1935), that the Raivola larch cultivated in Finland were almost purely of Ufa origin, can be rejected.

During the recent years the Raivola larch stand has been an object of cooperative studies by Russian and Finnish scientists and a detailed description of its history and current status has been published in Finnish and Russian (Redko & Mälkönen 2001) and also summarized in English (Redko & Mälkönen 2005). The forest has remained virtually untouched during its long history and even the oldest trees are still standing there. In the latest measurement in the beginning of 1990's the volume of the oldest stand (255 years) was 1284 m^3/ha. Currently the forest also belongs to the UNESCO world heritage list (Redko & Mälkönen 2001). Thus it can be said that the holders of the forest, irrespective of their nationality, have given it the respect which this most spectacular cultivated forest in northern Europe deserves.

6. Professional introductions

Soon after the establishment of the Finnish Forest Research Institute, its professor of silviculture, Olli Heikinheimo, started in late 1920's a large systematic programme with cultivation of exotic tree species. This work was motivated by promising results of the experiments in Mustila Arboretum (Tigerstedt 1922) and the writings by Ilvessalo (1920, 1923) and Cajander (1917). During a period of some 20 years several hundred hectares of cultivations of exotics were established mainly in the southern part of Finland. For several reasons the exact area of established plantations is difficult to obtain. In the first comprehensive report of the exotic cultivations the total area of them was 306 ha, but this figure does not include all failed plantations (Heikinheimo 1956). On the other hand his report contains also some cultivations from the time before the establishment of Forest Research Institute. To understand the whole scale of the work it must be added, that about 100 ha of cultivations were established on research areas which were later lost to Soviet Union in the Second World War (Heikinheimo 1956, Kakkuri 2006). The total amount of seedlings used for the cultivations was about 700 000 (Heikinheimo 1956). Currently there are cultivations at seven different research areas in southern and central Finland and at one area in northern Finland (Silander et al. 2000).

The cultivations included 110 taxa (species or lower level units), mainly conifers (69) (Heikinheimo 1956). The conifer plantations surviving at the end of 1990's were established from 176 seed lots (Silander et al. 2000). Most of the material came from North America (71 seed lots), from East Asia came 40 and from Europe 27 seed lots. Additionally, 38 seed lots came from older Finnish cultivations of unknown origin (Silander et al. 2000). Species with largest plantations were *Larix sibirica*, *L. decidua*, *Pinus contorta* var. *latifolia* and *Pseudotsuga menziesii* (Fig. 6). The two last mentioned species were represented by quite many different origins so that also comparative plantations could be established (Heikinheimo 1956). The average size of the cultivations is about 0.5 ha (Silander et al. 2000). There were no replicates in the cultivations, but usually the same material was planted in several research areas in different parts of Finland. During the existence of the plantations their growth and status has been described in three covering reports (Heikinheimo 1956, Lähde et al. 1984, Silander et al. 2000), the latter two containing, however, only the coniferous species.

Figure 6. A 80 years old stand of lodgepole pine belonging to the cultivations of professor Heikinheimo in Punkaharju in southeastern Finland. Photo T. Nikkanen.

In 1990's the Forest Research Institute started to update the old exotic cultivations in order to produce a new generation with the most promising species in the research areas (Savolainen & Silander 1993). To date some 90 ha of new plantations have been established with 58 conifer taxa (Teijo Nikkanen, Natural Resources Institute Finland (Luke), pers. comm.).

In addition to these silvicultural exotic cultivations also other research branches have used exotic tree species in their experiments. Most remarkable are the experiments established by forest geneticists since 1940's mainly for studying the geographical variation within exotic tree species. These experiments total 427 in number and cover an area of 380 ha (7% of all experiments in forest genetics). By area the most important exotic species are poplars (including hybrid aspen), larches (especially Siberian larch) and lodgepole pine (Natural Resources Institute Finland (Luke), Register of Forest Genetics). These experiments are especially valuable for including better adapted origins from many species which had earlier been represented only with much more southern material (e.g. *Picea mariana*, *Larix laricina*) (Fig. 7). These experiments have usually been established with small plots (typically 10 x 10 m) with a completely randomised block design, but in some cases also single tree plots have been used. Some of the experiments have been established in collaboration with other Nordic countries, for example, experiments with North American conifers in 1990's and the more recent SIBLARCH experiments with Russian larch species (for materials in these cooperative experiments see Skaret and Rosvall (1993) and Abaimov and others (2002)). Contrary to earlier cultivations of exotics these experiments also cover northern Finland, so that to year 2003 a total of 74 experiments with 22 exotic species had been established north of the Arctic Circle (Ruotsalainen 2006).

Figure 7. A 20 years old black spruce provenance experiment in Kolari, Lapland in the middle of 1990's. In the foreground (from left) are Seppo Ruotsalainen, Ossi Rundgren and Reijo Rauniomaa from the Kolari Research station of the Finnish Forest Research Institute. Photo T. Tasanen.

According to the results from the old experiments by professor Heikinheimo there are only a few exotic tree species, which can have some value for forestry in Finland (Silander et al. 2000). In line with earlier studies and experiences, European and Siberian larches, lodgepole pine and Douglas-fir belong to this group. In addition also *Abies sachalinensis*, *Picea omorika* and *Pinus peuce* may have potential for forestry use in southern Finland. In northern Finland black spruce (*Picea mariana*) has also been used on frost prone sites due to its rather good performance on such sites (Reinikainen 1997). A proof of the production potential of the exotic tree species is the fact that both the tallest and by the volume greatest trees in Finland are exotics – the former is a European larch in Punkaharju (47 m) and the latter is a poplar (*Populus* 'Rasumowskiana') in Heinola (30 m^3). (Esko Oksa, Natural Resources Institute, pers. comm.).

In spite of extensive and occasionally also intensive testing of exotic tree species they have not gained more than marginal importance in Finnish forestry. Only Siberian larch and lodgepole pine have been planted on a larger scale, but the share of both total area and volume of all exotic tree species in Finnish forests is only 0.1% (Korhonen et al. 2013). The very limited use of lodgepole pine in Finland in comparison to Sweden is remarkable, although there are two separate waves for its introduction. First of them was in the beginning of the 20th century starting from the experiments in Mustila and motivated by its suitability for pulp wood, also with sulphite pulping process (Hakkila & Panhelainen 1970). Finland has in fact been pioneering country in large scale planting of lodgepole pine in Europe (Tigerstedt 1975). Second and by area a more important phase aiming for high volume production in 1970's was inspired by the Swedish boom in planting lodgepole pine.

7. Understanding the importance of the origin

The poor success of many of the early cultivations of exotics can be explained by the unsuitability of the species and provenances (the geographic origin) of the introductions. It cannot be claimed that there had prevailed total ignorance as regards the climatic adaptation of the trees, but in many cases practical difficulties directed the acquisitions to too warm climates relative to Finnish conditions. For instance Linné motivated the selection of New England as the destination for the expedition of Kalm by its similarity of climate and soil to Finland (Hjelt 1896). Also Gadd held the opinion that *Morus alba* var. *tatarica* would be the most climate tolerant of all mulberry trees and suitable for Finnish climate, but he was not able to obtain it for his experiments (Johansson Åbonde 2010). In comparing the climates of different geographical areas, perhaps too much attention was paid to the strength of the winter, although Kalm had thoughts that the length and warmth of the growing season could play an important role in the hardiness of the trees (Kukkonen 1979). Already in 1757 there was a publication in the Academy of Turku, in which the origin and quality of the seeds for growing apple trees was emphasized. Southern origins were not suitable for Finland. (Oja 2008).

When the genetic basis of the climatic adaptation was not known, the prevailing idea was to acklimatise tender species to Finnish conditions by cultivating them here long enough (Nummi 2008). To the end of the 19th century the theory behind this method obtained also features of genetic selection within population (Niklander 1892). Temporary successes could sometimes be achieved by this method, if by chance or on purpose the planting site or climate were favourable. Generally, however, it led to a large number of failures.

Understanding the importance of the climate of the site of the origin in determining the success of an introduced tree species began to develop in 1870's when cultivation of exotics for forestry purposes started anew in Germany and other central European countries (Cajander 1923). This idea was clearly expressed at species level by professor Heinrich Mayr from Munich, although he did not extent it to cover the climatic variation within the species distribution area. The receipt of Mayr was first to study the climatic conditions of the possible donor areas, select the best matching areas for the sources of introductions and then test the material in the recipient areas ("Erst studieren, dann probieren"). Cajander (1923) called this "deductive inductive method". Through comprehensive theoretical studies the number of potential species can be narrowed down substantially, but for the final answers field testing is needed, because the climatic conditions are usually never known well enough and the match is seldom exact.

The method of matching the climates of donor and recipient areas was successfully applied and even improved to also cover the within species variation by A. F. Tigerstedt in his Mustila arboretum (Ilvessalo 1926). It must be emphasised that the suitability of a species in a new environment cannot be determined until the best adapted provenances of it have been tested (Figs. 8, 9). Already Cajander (1917) pointed out several areas matching climatically closely enough Finland to serve as source for successful introductions of exotic tree species. Most attention of them have gained western North America, Far East and Central European mountains (Silander et al. 2000).

Figure 8. Different provenances of subalpine fir (*Abies lasiocarpa*) in 77 years old plantations in Punkaharju, southeastern Finland. On the left is a provenance from Washington (46 °N), on the right a British Columbian provenance (51 °N). At the age of 64 years the mean height and volume per hectare were 11.5 m and 176 m^3 for the provenance from Washington and 21.1 m and 397 m^3 for the provenance from British Columbia (Silander et al. 2000). Photo T. Nikkanen.

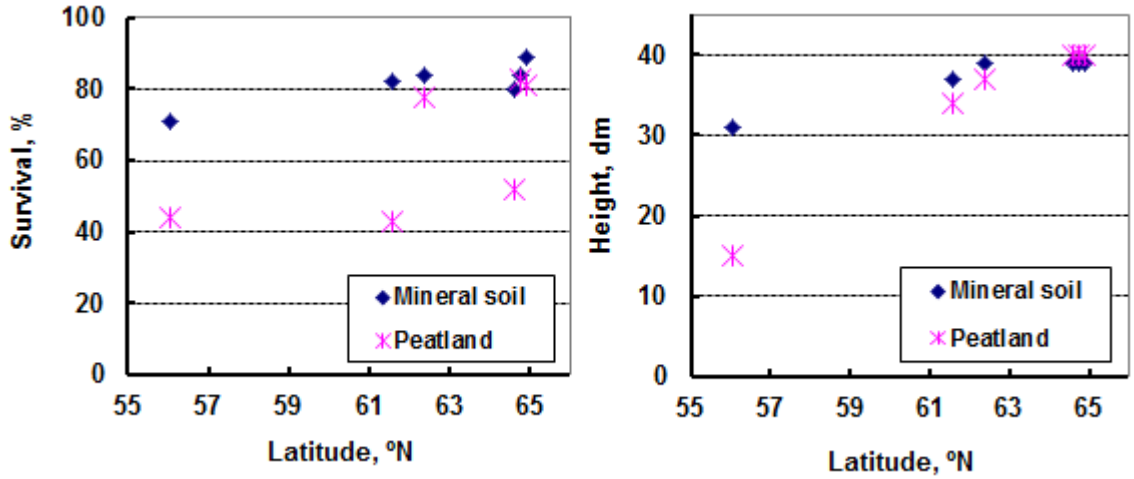


Figure 9. Survival and mean height of different geographical origins of black spruce in two experiments with different soils in Kolari, Lapland (latitude 67 °N) at the age of 20 years (the experiment on mineral soil can be seen in Fig. 7) (from Ruotsalainen 2006).

8. From history to the future

It can be seen that during the introduction history of exotics the driving forces have differed. In the beginning the idea was clearly to introduce to Finland species producing commodities which our native trees are unable to deliver. Examples of this are fruit trees and mulberry trees for production of silk. Also the establishment of Raivola larch stand was motivated by production of valuable wood material for building ships. Later on the arguments for planting exotics changed more into direction of better volume production or resistance to adverse environments (Table 1). Due to the current global markets it is probable that in future the cultivation of exotics cannot be motivated by some narrow national economic goals, but the justification for their use must be sought from improving the biological and economic productivity and stability of forest ecosystems.

Table 1. Purposes for using some exotic tree species in Finland during different time periods.

Species	**Time of use**	**Reason for use**		
		Better growth	**Better resistance**	**Special quality or product**
Fruit trees	Middle Ages?-			X
Morus sp.	1700's			X
Crataegus coccinea	1700-			X
Larix sibirica	1700-			X
" "	1800-	X		(X)
Pinus contorta var. *latifolia*	1920-30	X		X
- - " - -	1970-	X		
Pseudotsuga menziesii	1900-	X		(X)
Picea mariana	1970-		X	

In the history of cultivation of exotic tree species one can discern a repetition of similar phases in different time periods. The initial enthusiasm can lead to excessive expectations and to unplanned and poorly managed establishment of cultivations. After misfortunes and unfulfilled expectations the interest starts to fade and the cultivations are left without management. This has been the development e.g. with the cultivations in Turku in the middle of 18th century and in Evo in late 19th century (Ilvessalo 1913, 1926, Kukkonen 1979). In short: there is often too much enthusiasm and too little professionalism in the work with the exotics. The management of forest cultivations requires long-term commitment, especially in the case of exotic species which can require more intensive care than the native ones.

Compared to the extent of cultivations with exotic trees not too many thorough studies of them have been made. Unfortunately also this is familiar from the history, as already Ilvessalo (1920) noted that compared to the long time used for testing of exotic trees the results were rather scanty. Most of the studies have been on the descriptive level, with exceptions of some studies with larch and lodgepole pine (e.g. Vuokila 1960, Varmola et al. 2000). Especially the possibilities for studying the effect of geographic origin on the growth and success of cultivation have been largely neglected. A positive exception in this respect comes from the youngest experiments; the SIBLARCH material has been processed in less than 10 years to an academic dissertation (Fig. 10) (Lukkarinen 2013). In order to find the best possible material the success of the existing cultivations should be systematically studied and possible gaps in testing of the potentially suitable seed origins should be identified and filled in (Ruotsalainen 2010).

Figure 10. A five years old SIBLARCH provenance experiment of *Larix sibirica* (left) and *L. gmelinii* (right) in Punkaharju in autumn colours. Photo S. Ruotsalainen.

The low number of important tree species in forestry is both a benefit and a limitation. For the forest industry the need to handle only a few species means savings in the costs, but on the other hand also a risk, if the silvicultural or business environments will change. However, the diversification of the assortment of the available tree species is prevented by the vicious cycle of supply and demand, especially if the wood characteristics require different processing. Forest owners are not interested in planting exotics if there are no markets for them and forest industry is not interested in developing special processing techniques for species which are not available in great amounts. In the near future only Siberian larch will have some practical use in Finnish forestry. It is regarded as a native species in the forestry certification rules and there exist both a breeding programme and seed orchards for it (Criteria for Group… 2009, Haapanen & Mikola 2008).

With a longer time perspective cultivating exotics should be encouraged, because they can be regarded as an insurance for changing climatic or economic conditions, which may require new species or commodities (Winder et al. 2011). Collecting experiences and maintaining cultivation tradition of the exotics can prove valuable in the changed conditions.

Acknowledgements

This article is based on a presentation in a Nordic Forest Historic Conference in Reykjavik, Iceland, on 13th September 2013. The earlier version of the manuscript was read by Boy Possen, Antti Lukkarinen and Thröstur Eysteinsson, who made many constructive suggestions both to the content and the language of it. Their efforts to improve my text are gratefully acknowledged. Seppo Oja helped me to find relevant old literature. Teijo Nikkanen, Tapani Tasanen and Erkki Oksanen gave me their photographs to be used for the illustration of the article. I thank all them for their help in my effort.

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