Comparison of yield of Norway spruce (*Picea abies*) and Sitka spruce (*Picea sitchensis*) in Skorradalur, West Iceland

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Master Thesis no. 168

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Abstract

Iceland has suffered from massive deforestation since the Vikings settled on the island in 874. The woodland cover has gone from 25-30% to 1 %. Since the beginning of the 20th century, effort has been made to regain the forest. In these afforestation efforts many tree species have been used both indigenous and exotic. Coniferous species have played a major role in this afforestation. Species such as Siberian larch, Norway spruce, Sitka spruce and various pine species have been important in these efforts.

The two spruce species mentioned earlier have both been very important in the afforestation of Iceland. However, the usage of Norway spruce has declined through time whereas usage of Sitka spruce has increased.

This study was carried out in a forested area in West Iceland owned by the Icelandic forest service. The aim of the study was to find out how much yield difference is between Norway spruce and Sitka spruce in this area.

The result shows a very big difference between those species and in all aspects the Sitka spruce has higher values. The average difference for stands 46-55 years old for total mean annual increment this is 3,7m^3/ha/year or 86,9% more for Sitka spruce compared to Norway spruce.

Key words: Iceland, Norway spruce, Sitka spruce, volume yield, mean annual increment.

Foreword

My name is Valdimar Reynisson I am an Icelandic forester. This is my master thesis for 30 credits in forest management following my studies at the Euro forester program in Alnarp hosted by the Southern Swedish Forest Research Centre.

The study was my idea and was laid out by me with the help of my supervisor Eric Agestam. All measurements calculations and writing are entirely my work and I had no sponsors. I was allowed to do this study by the landowners and got all the necessary data from them that I needed for my work.

The idea for this study came because in the area of the study both species are in much quantity, and have highly important I have noticed a big difference in the size of these species and wanted to know how much the difference really was. This is also the region where I live. I believe that Sitka spruce is the future timber tree for this area and I have a great interest to see how it is compared to Norway spruce.

Measurements were performed in the autumn in 2008, but the writing and calculations have taken more time than expected.

I hope the result from this study can help to improve Icelandic forestry in the future.

Alnarp 6.may. 2010
Valdimar Reynisson

Table of content

1. Introduction

The Icelandic forests and woodlands have suffered a catastrophic decline since 874 when the Vikings settled on the island. The woodland cover went from 25-30% to as little as 1% around 1900. There have been efforts to recover the forested area in Iceland since the beginning of the 20^{Th} century. Today Icelandic forest area is increasing because of the effort of a few believers that never gave up

Norway spruce *Picea abies* and Sitka spruce *Picea sitchences* have played a major role in the afforestation, among other species.
The interest in Norway spruce has declined because Sitka spruce is growing much better but still there are people that want to promote the Norway spruce.
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The aim of this study is to find out how much more productive Sitka spruce is compared to Norway spruce. These two species are the most used spruce species in Iceland. Sitka spruce is the future timber tree for Iceland but the Norway spruce has been used for longer time and there is a willingness with in the forest sector to promote the Norway spruce as timber tree even though usage of Norway spruce has declined and is now almost only planted as Christmas trees.

The importance of the results is to find out which one of these species is most suitable to be used in forestry and how much more the species are producing in this area. It is important to know this for future planning and to get as good outcome as possible in these conditions. The result gives clues about the importance of provenances for production.

This report starts with a chapter about the Icelandic forest history and after that is a short overview of the location of the study, then materials and method, results and discussion and conclusions.

1.1 Forest history in Iceland

Before the settlement

Iceland is a young island and the oldest lava is 16 million years old. The area of the island is 103000km^2 and it is located in the North Atlantic Ocean 63°N-66°N, 18°W-22°W, between Greenland and Norway. The northern part touches the Arctic Circle.

During mid tertiary (5-15 million years ago), the climate was warm tempered, Iceland was very forested at this time. Fossils show that tree genera included *Sequoia, Magnolia, Sassafras, Glyptostrobus.* Beech (*Fagus sp)* forests were common at this time (Blöndal & Gunnarsson; 1999. Eysteinsson, 2009). About 3 million years ago in late Pliocene just before the glaciations began (Plistocene glaciations), the forest was dominated by genuses such as *Pinus, Picea, Abies, Larix, Betula and Alnus*, that indicating a boreal climate (Eysteinsson, 2009). At the time of the Ice age it is likely that Iceland was almost covered with Ice but few mountains where reaching above the icecap and on these mountains vegetation survived (Símonarson, 1981). During the Ice age, the temperature shifted from cold to not as cold periods. According to fossil research *Pinus*, *Alnus*, *Betula* and *Salix* grew in Iceland until about 1 million years ago , then *Pinus* died and 500.000 years ago the *Alnus* also died. That period was the last and the coldest of the Ice age, vegetation was then similar to modern vegetation (Blöndal & Gunnarsson, 1999).

12-10 thousand years ago the temperature rose rapidly and the glaciers declined rapidly and vegetation started to spread (Einarsson, 1981). Climate was ideal for birch about 9000 years ago and at that time birch spread rapidly. This period is called the earlier birch period and it lasted for 2000 years. Then a colder period named the earlier mire period came and birch declined, this period lasted for 2000 years. 5000 years ago the climate was warmer again and birch increased again in this second birch period that lasted for 2500 years and then a cold period started again, called the second mire period and this period still exist (Blöndal & Gunnarsson, 1999). From the start of the second mire period to the time of settlement the temperature had dropped about 2-3 °C in average and forest declined (Ragnarsson, 1988). Colder climate can explain decline in forest cover through lower elevation of tree line but not deforestation on lowlands (Eysteinsson, 2009).

After settlement

In the year 874 the settlers came to Iceland. The forest cover was 25-30% of the total area of the island. (Blöndal & Gunnarsson, 1999). The forest at settlement reached from the height of 15m in sheltered valleys and graded to birch and willow shrubs at the coastline and mountains (Eysteinsson, 2009). Icelandic natural Forests contain seven tree species they are: Downy birch, *Betula pubenscens*, rowan *Sorbus aucuparia,* aspen *Populus tremula* as top layer species. The ground layer species are tea-leaved willow *Salix phylicipholia*, woolly willow *Salix lanata*, arctic willow *Salix arctica* and the common juniper *Juniperus communis*.

In the old Icelandic sagas there are stories about the forest covering Iceland from the coast to the mountains and there is butter dripping from every straw. This indicates the fact that this was a good place to live, good for agriculture, enough food and firewood. But this was about to change. In 1000 years forest cover decreased from 25-30% to 1% (Figure 1 and 2).

Figure 1. The forest cover at the time of the 19th settlement.

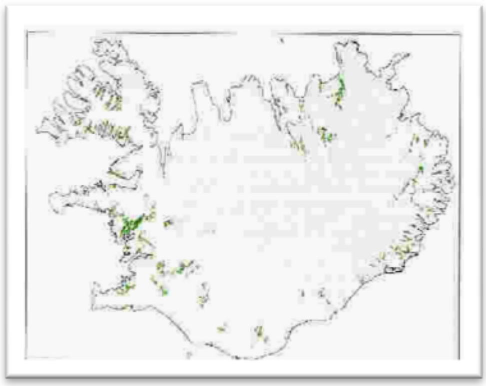


Figure 2. The forest cover at the end of the century.

There are many reasons why this decline took place. The human impact with cutting trees to make fields for agriculture and grazing played the biggest part in the declining of the forest. People needed wood as firewood, building material and fodder for livestock.

Charcoals was the most important product of the forest. People needed charcoals to make iron from the mires. The iron from the mires was not of good quality so it frequently needed reforming with heat and for that much charcoal was needed. The need for charcoal for this type of usage lasted to the beginning of the 20th century when Icelanders started to import steel tools for agriculture, like a scythe from Scotland 1868 (Blöndal & Gunnarsson, 1999; Eysteinsson, 2009).

The agriculture was small scale and more or less on survival basis, the aim of the farming was to keep the family alive. Proper tools or knowledge to make descent hay fields were missing and therefore grazing of livestock was necessary and the forest was ideal for grazing.

Declining forest cover led to soil erosion, which led to desert formation. Other natural causes such as volcanic eruptions played a big role in the deforestation of Iceland as well.

Even though warning signs were obvious little was done to stop this development, until in the end of 19th century when a Danish merchant and marine captain, Carl Ryder and his friend Carl Vilhelm Prytz a Danish forestry professor, together with Christian E, Flensborg a Danish forestry student started a program called "Islands skovsag" (Icelandic forest matters). This program is the start of afforestation in Iceland (Blöndal & Gunnarsson, 1999).

110 years of forestry

The first successful planting of coniferous trees was in the year 1899 in Thingvellir, in "The Pine Stand" The survival the first winter was bad but few specimens of Mountain pine *Pinus uncinata (P.mugo. var.rostata= P.uncinata;)* survived along with Silver birch *Betula pendula* and Downy birch *Betula pubencens* (Bragasson, 1995). This gave the Icelanders hope that it was possible to grow forest with other species than the indigenous. At the beginning, the production of seedlings was meagre, because seeds were not easy to get. In some years there were no seeds but in other plenty. Conditions in tree nurseries in Iceland were also different from other countries, this led to high mortalities and importing of seedlings (Blöndal & Gunnarsson, 1999). Delivery of seedlings from the nurseries was 1-15 thousand each year until 1938 then 20 thousand seedlings were delivered for the first time (Pétursson, 1999). The first 7 years the Danish forester Christian E. Flensborg tried 26 species, of them 13 survived and 8 of these species are still used in some amount, for instance Siberian larch and Norway spruce.

In 1907 the first forest law was established. In 1908, the Danish forester Agner F.Kofoed-Hansen was hired as the director of forestry in Iceland and the Icelandic Forest Service was founded. Kofoed-Hansen was not happy with the result from the nurseries, so in 1912 he announced that experiments in growing foreign tree species should stop and the last seed was sown in 1913. Siberian larch was the only species that Kofoed-Hansen thought had a chance. After that the focus was on the indigenous forests, to protect them, spread them and get more production from them with the right silvicultural method (Blöndal & Gunnarsson, 1999).

The main aim of the forestry was to stop deforestation and regenerate the native birch woodland, by protecting it from grazing. In the year 1930, the Icelandic Forest Association (an umbrella organisation for the local forestry societies) was founded. It is now the largest environmental NGO in Iceland with roughly 7000 members (ca 2,5% of population) (Eysteinsson, 2009). The Icelandic Forest Association has played a major role in the afforestation in Iceland. Until 1990 they had 50% of the forested area, the other half was done by the Icelandic Forest Service. The main activities of the forest societies are close to towns and cities, which mean that the focus is on recreation. The forest societies are carrying out 1,5% of the total planting today (Blöndal & Gunnarsson, 1999; Eysteinsson, 2009).

At the end of Kofoeds-Hansens time in 1933, Siberian larch was sawn again in Hallormsstaður. This event is the starting point of the next period in Icelandic forestry. From this time and to 1950 many seed gathering expeditions were made to Alaska and other places to get more species to grow in Iceland. The first major seed delivery from Alaska arrived 1941-1942. The first seeds of Scots pine came in 1937 but it took ten years for the species to become the prime species in Icelandic forestry (Blöndal & Gunnarsson, 1999). In 1946, for the first time, there were delivered more than 100 thousand seedlings from the nurseries. Afterwards plantation started to be noticeable and the forest sector started growing (Pétursson, 1999).

Around 1950 coniferous species became much more important than before when the governmental forest policy was to produce 80% of the timber that was required in Iceland.

The period after 1950 can be divided into shorter periods according to the main tree species at each time. Fore instants the period of Scots pine from 1947-1960, the Sitka spruce period 1951-1963 and again from 1986, Norway spruce period from 1958-1972, period of Siberian larch from 1961 and period of Lodge pole pine 1965-1985 and 1992 (Blöndal & Gunnarsson, 1999).

The number of seedlings reached 1 million in 1958 and in 1961 1.5 million. However, after 1963 the number of delivered seedlings dropped under 1 million. This situation lasted until 1983. After 1983 the number of seedlings has increased much (Pétursson, 1999).

In 1961 the Norwegian king gave the Icelandic nation one million Norwegian kroner as a thanks for their support in the Second World War. The money was provisioned to strengthen Icelandic forestry. This resulted in the forest research centre that opened August 15. 1967, when the Norwegian prince handed the gift to the Icelandic forest service.

Two major catastrophes occurred in Icelandic forestry 1963.

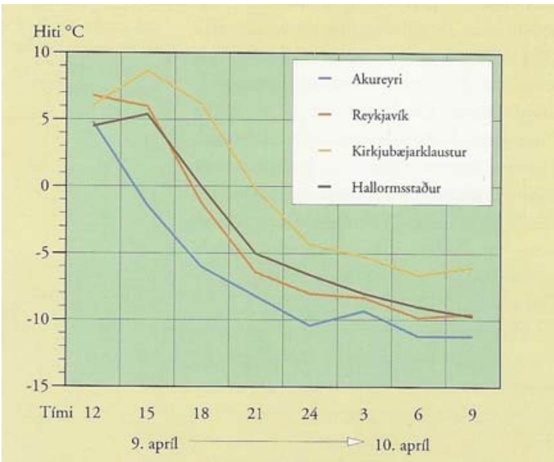


Figure 3. The temperature drop in April 1963 (Blöndal og Gunnarsson, 1999).

March 1963 was unusually warm, almost 4°C above average. In this warm weather, trees were fully leaved and had started to grow especially in the south and west of Iceland. The 9th of April temperature dropped 16°C to about -10°C in 12 hours causing tree species from North America severe damages or death.

Some poplars and willows were frost bitten to the root and some trees split down to the root. The most sever damages was in the south and west but less in southeast and least in the east. In this weather conditions, over 400 thousand Sitka spruce seedlings died (Figure 3) (Blöndal & Gunnarsson, 1999).

The second catastrophe 1963 was that the insect *Pinus pini* most likely brought here by seedlings from Norway, wiped out all the Scots pine (Þorsteinsson, 1990).

These two catastrophes lowered the positive moral about afforestation of Iceland, and only a few believers of forestry kept the spirit alive. Public interest dropped and a lot of negativity against forestry occurred.

1955 a new forest law was decided by the government, with some improvement in 1958. These laws are still the basic laws of forestry today with small improvements here and there.
In the year 1990 a new phase was reached in Icelandic forestry, when the number of seedlings increased to over 2 million (Jónsson (ed), 1991) and in 1993 delivered seedlings were 5 million (Pétursson, 1999). Since 2000, annual plantings have been 5-6 million seedlings per year (Gunnarsson, 2001-2008).

1990 regional afforestation project started in the east, Héraðsskógar. The aim for this project was to help and get farmers interested in growing forest on their land (Eysteinsson, 2009). This experiment was successful, in 1999 such projects had been established in all parts of Iceland, and a special law was established with the aim to afforest 5% of land area below 200m altitude before 2040. The Regional Afforestation projects is responsible for 80% of the total planting in Iceland today.

In 1990 another project was launched, the soil conservation forest, managed by the Icelandic Forest Association in cooperation with the Icelandic Forest Service and the Soil Conservation Service of Iceland, this project is now planting about 12% of the total seedlings planted in Iceland today

The Hekluskógar (Hekla woodlands) project was established in 2005. This is the largest restoration project in Iceland covering 90 thousand hectares or about 1% of Iceland. This area is situated around mount Hekla, an active volcano in south Iceland. Tephra (products from volcanic eruption other than lava) is covering large areas there. It is easily moved by wind and rain and has very low plant nutrient level and water storage ability. The aim of this project is to reclaim former vegetation and woodlands. The method is to plant downy birch and willows in “tree islands” in the area. These islands will then serve as a seed source and increase their area as a natural development. The stakeholders for this project are local landowners, local afforestation societies, the Soil Conservation Service and the Icelandic Forest Service, the South Iceland afforestation project and the Afforestation Fund of Iceland (Aradottir, 2005).

Table 1. The number of planted seedlings in Iceland in the year 2007 (Gunnarsson, 2008).
*Seedlings and cuttings

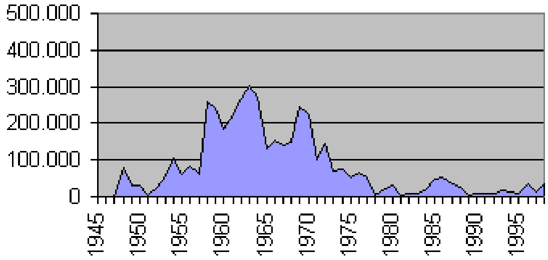
Rank	**Common name**	**Latin name**	**No of seedlings**	**% of total**
1	Siberian larch	Larix siberica	1.530.177	24.80
2	**Sitka spruce and Lutz's spruce**	**Picea sitchencis/ Picea x lutzi**	**1.378.755**	**22.34**
3	Downy birch	Betula pubescens	1.367.529	22.16
4	Lodge pole pine	Pinus contorta	777.115	12.59
5	Black cottonwood *	Populus trichocarpa	332.075	5.39
6	Engelmann spruce	Picea engelmanii	149.229	2.24
7	Rowan	Sorbus aucuparia	89.281	1.45
8	Silver birch	Betula pendula	85.115	1.38
9	Sitka alder	Alnus sinuata	68.275	1.11
10	White spruce	Picea glauca	59.750	0.97
11	Willow various sp	Salix sp	37.940	0.61
12	Felt leaved willow	Salix alexensis	36.472	0.59
13	Swiss stone pine	Pinus cembra	34.104	0.55
14	**Norway spruce**	Picea abies	**22.975**	**0,37**
15	Woolly willow	Salix lanata	20.110	0.33
16	Hreggstaðavíðir	Salix phylicifolia x S. borealis	17.000	0.28
17	Mountain pine	Pinus uncinata	15.280	0.25
18	Alder various sp	Alnus sp	14.070	0.23
19	Tea-leaved willow	Salix phylicipholia	13.602	0.22
20	Scots pine	Pinus silvestris	13.331	0.22
	Other species		96.176	1.56
	Total		**6.170.937**	**100**

In Icelandic forestry today the Sitka spruce is one of the most important species, but the importance of Norway spruce has declined. Norway spruce is mostly used for Christmas trees (Table 1).

In the country report for FAO from 2005 it is shown that the total forest and other wooded land cover in Iceland is150.000 hectares or 1,5% of the total land area. Forest is 46 thousand hectares and other woodlands are 104.000 hectares. The ownership of these areas are mainly private 69 %, public ownership is on 29% of these areas and 2 % is owned by others. Growing stock in these forests is 1.129.000 m^3, in native forests and other woodlands 1.887.000 m^3 and in woodlands 2-5 m high 368.000 m^3. This can be seen in table 2 (Snorrason et.al, 2005).

Table 2. The growing stock in Icelandic forests. This table is based on data from the country report from FAO (Snorrasson et.al, 2005).

	Growing stock in forests (million m^3)			
Species	**1990**	**%**	**2000**	**%**
Downy birch *betula pubescens*	1,940	86,6	2,020	75,4
Sitka spruce *Picea sitchensis* (Bong.) Carr.	**0,090**	**4,0**	**0,180**	**6,7**
Siberian larch *Larix siberica* Ledeb.	0,040	1,8	0,160	6,0
Lodgepole pine *Pinus contorta* Dougl.	0,030	1,3	0,090	3,4
Norway spruce *Picea abies*(L.) Karst.	**0,020**	**0,9**	**0,040**	**1,5**
Mountain pine *Pinus uncinata* Mill. Ex Mirb.	0,016	0,7	0,031	1,2
Black cottonwood *Populus trichocarpa* Torr.& Gray	0,004	0,2	0,019	0,7
Engelmann spruce *Picea engelmanni* Parry	0,008	0,4	0,018	0,7
White spruce *Picea glauca* (Moench) Voss.	0,006	0,3	0,010	0,4
Rowan *Sorbus aucuparia* L.	0,006	0,3	0,007	0,3
Other species	0,080	3,6	0,105	3,9
Total	**2,240**	**100,0**	**2,680**	**100,0**



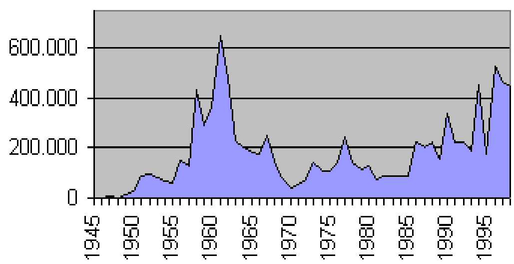


Figure 4. To the left delivered Norway spruce seedlings in Iceland from 1945-1999. To the right number of seedlings of Sitka spruce delivered from nurseries from 1945-1999 (Pétursson, 1999).

Norway spruce was planted quite much in the period 1955-1972, but since then Norway spruce has had very little usage (Figure 4). The Sitka spruce has two periods were it is planted the most first the period from 1950-1963 and then from 1986 until now and it is now the second most planted species in the country as seen on tables 1 and 2 (Blöndal & Gunnarsson, 1999. Pétursson,1999).

1.2 Use of wood

There is no actual forest industry in Iceland. Until now the main usage has been for firewood, fence poles and hand craft. Following economic crisis, the market for industrial wood has developed slowly in Iceland.

Now several companies are making sawdust for animal bedding and they are buying much of the available timber in the South and West Iceland. In the summer of 2009 Elkem Iceland and The Icelandic Forest Service accompanied by The National Forest Owners and the Icelandic Forest

Association started a experimental project. Elkem Iceland is buying fresh round wood to use for a new high quality product. Elkem will need a considerable amount of round wood in the future.

In the east, there is a wood heating project Skógarorka (forest energy) in a “cold area” (area that does not have natural hot water). They are heating up a Hotel, school and a swimming pool and the plan is to heat up the entire village.

There is only one machine in Iceland to cut tiles out of round wood. The tiles are for house coating but this is still an experimental project. There is some sawing done but it is random and no industry around it. It is mainly special orders from customers; the Icelandic forest service is sawing the most.

In 2010 a company was established to build pallets from Icelandic timber, they are buying stocks that are bigger than 15 cm in diameter.

A few small companies are bidding on the thinning in a tendering system for the bigger forest owners. Thinnings are performed with chainsaws, there are no harvesters in Iceland but there are few cutting heads on diggers.

1.3 Skorradalur

The Skorradalur valley is formed by a glacier around 10000 years ago. It is 25 kilometres long and narrow except at the west end. In the middle of the valley is a lake 16 km long and with an area of 14,7 km^{-2}. The combination of forest and lake makes this area popular for summerhouses.

The closest weather station is in Hvanneyri about 20 km away. There the annual precipitation is about 1051 mm in average and there are about 181 days/year that have +5°C or more in temperature annually.

The Icelandic Forest Service owns the forest area were this study took place. The forest is about 100 ha, it was established in 1952, and most of it is planted in the years 1952 -1975. The forest is mainly coniferous species. Sitka spruce and Norway spruce are the dominant species in this forest, also Lodge pole pine *Pinus contorta*, Mountain pine *Pinus uncinata* and Siberian larch *Larix siberica* are there in some quantity.

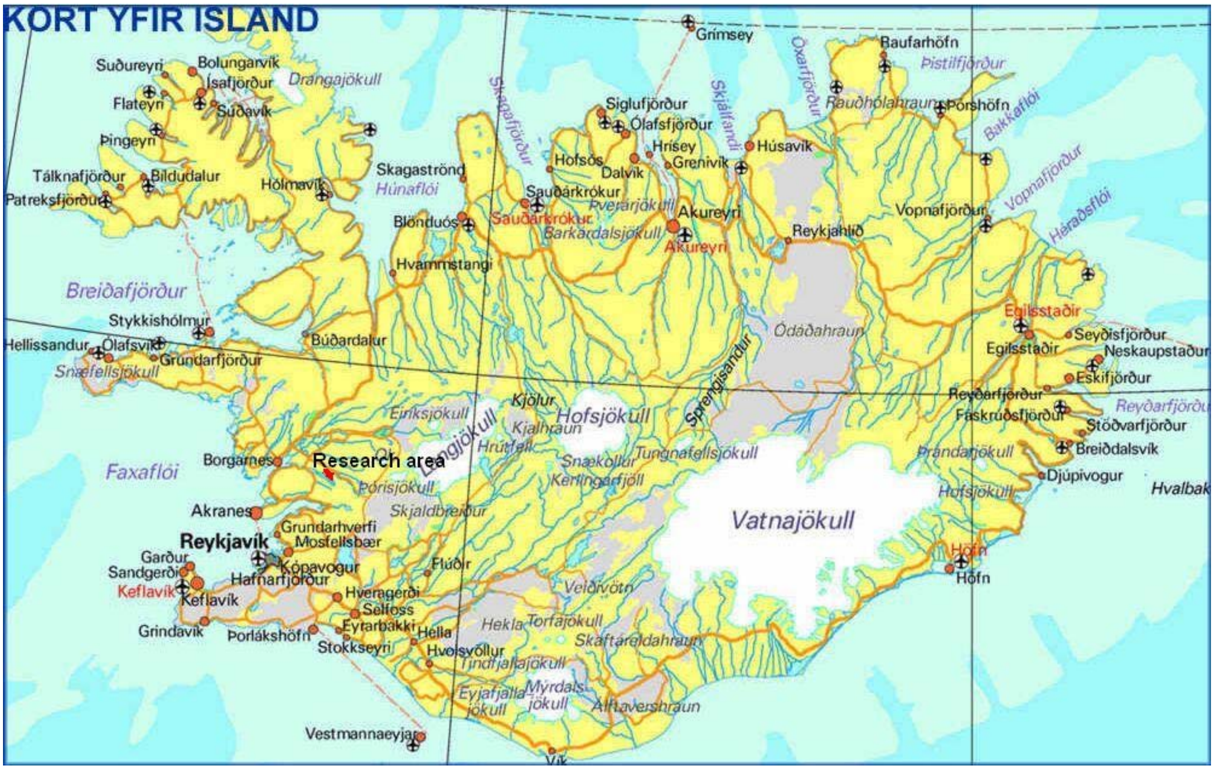


Figure 5. The red dot shows the location of the reasearch area. (The basic map is from the University of Iceland).

The forest at Stálpastaðir in Skorradalur (Figure 5) is ideal for such research because there are stands with each specie side by side established the same year. This made it possible to build pairs with two stands, one Sitka- and one Norway spruce. By measuring stands with the species growing in comparable conditions at the same place, we should get a good comparison of the growth and yield.

1.4 Norway spruce

Norway spruce *Picea abies* (L.) Karst. has a very wide distribution, it grows from the Ural mountains in the east the 41° N and to maritime alps in France, The most northern distribution is at 69°-72°

(Farjon, 1990). The Norway spruce which is growing in Finland and the old Soviet Union is sometimes said to be a separate species; *P.obovata* Siberian spruce (Þorsteinsson, 1990). The distribution of these two species is usually connected (Figure 6) (Vidaković, 1991).

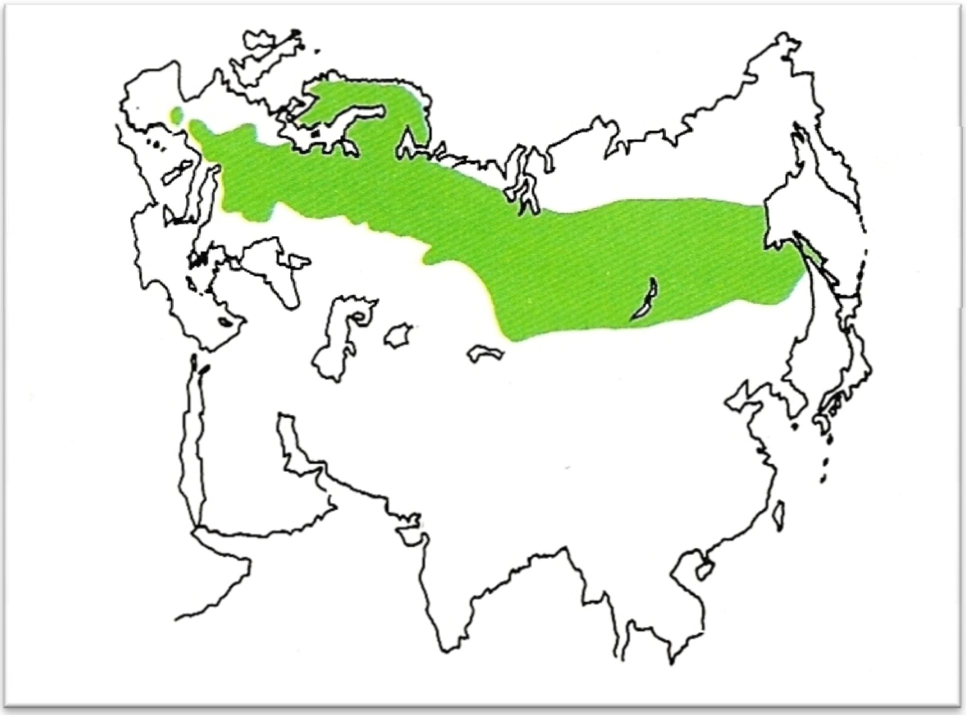


Figure 6. Natural distribution of Norway spruce and Siberian spruce (Þorsteinsson, 1990).

Both *P. abies* and *P.obovata* grow from sea level up to an altitude about 3000m. They grow on variable acid soil, peaty to rocky with medium-high to high ground water level (Farjon, 1990).

For the best growing ability the Norway spruce needs high nutrient (abundant) atmospheric moisture and cold, light acid porous and humus soil (Vidaković, 1991).

History in Iceland

Norway spruce is one of the first coniferous species that was successful in Iceland; it became one of the most important species at the early stages of Icelandic forestry a long with Scots pine and Downy birch. For most of the period 1958-1972 Norway spruce was the most planted species in Iceland as seen on Figure 4 (Blöndal & Gunnarsson, 1999. Pétursson, 1999).

Norway spruce has been used for Christmas trees in Iceland. The first Icelandic Christmas trees were cut 1955 and ever since has Norway spruce been the major source of Christmas trees in Iceland. But today Norway spruce is behind Icelandic grown Lodge pole pine and Nordmann fir *Abies nordmanniana* imported from Denmark on the Christmas tree marked (Gunnarsson, 2008). Nevertheless, it still has a big share in the Christmas tree market. In all other aspects it has the same usage as Sitka spruce.

Damages

Moose and other wild herbivores are not found in Iceland. However, reindeers are in the east but not in the region of this study. Domestic sheep is the grazing animal that does the most damage in Icelandic forests. Therefore planted forests are always fenced.

Norway spruce does not have a big problem with insects, diseases and other damages in Iceland. The root rots fungi *Heterobasidium sp* has not yet been found in Iceland, and damages by windfall is not a big problem yet. However, snow damages can occur to some extent especially in younger stands.

In the year 1999, spruce rust *Chrysomyxa abieties* was found in the west and south parts of Iceland. In wet summers, it can be seen in forests in west and southwestern part of Iceland, this disease is not doing any major damage to the forest.

Rhizosphaera needle cast *Rhizosphaera kalkhoffii* is found in Iceland. It thrives on many spruce species but in Iceland, it is doing the most damage on the Norway spruce but still not a big problem.

1.5 Sitka spruce

Sitka spruce *Picea sitchenses* (Bong.) Carr is the largest of all spruce species. (Thompson & Harrington, 2005). It can reach maximal height from 60-90m, and DBH up to 4-5 m. (Farjon, 1990). Sitka spruce grows in a narrow strip on the west coast of north America from Alaska 61°N to California 39°N as seen on Figure 7 This strip is 3000 kilometres long and is never wider than 200 kilometres (Figure 7) (Vidaković, 1991). Sitka spruce has been used commercially in some countries in Europe, for example Denmark, Norway and Great Britain (Thompson & Harrington, 2005).

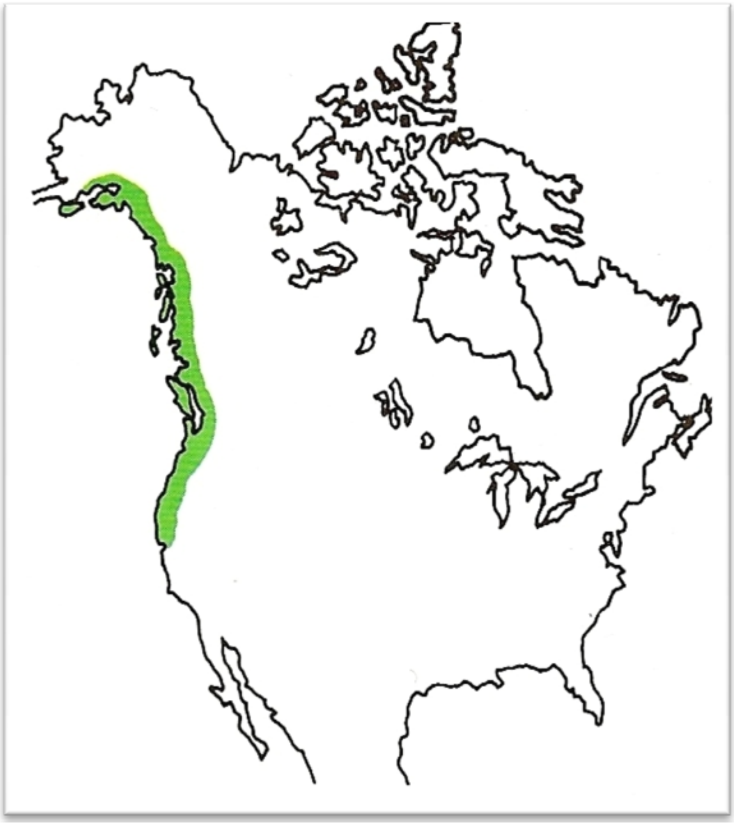


Figure 7. Natural distribution of Sitka spruce (Þorsteinsson, 1990).

Sitka spruce grows best in maritime climate, mild winters and cool summers, with annual rainfall about 1000 - 3000 mm per year (Thompson & Harrington, 2005). Sitka spruce is a lowland species and is rarely found in altitude more than 1000 m above sea level. Sitka spruce grows in various fresh to moist soils. However, the best growth is gained in deep, moist and well-drained soils. Sitka spruce grows slowly at young age but as it gets older, the growth is more rapid (Vidaković, 1991).

History in Iceland

The first seeds of Sitka spruce arrived in Iceland in the period 1920-1930. There are a few trees still living from these seeds (Blöndal, 2004). The oldest sitka spruce in Iceland is probably in Reykjavík. It was planted 1924 (Svanbergsson, 1989). Major plantings of sitka spruce started in 1937 when plants came from a nursery in Norway (Blöndal, 2004). The oldest Sitka spruce in Skorradalur is from 1938 in a small forest that a youth club planted. This forest is now mature. Friðrik Aspelund a private forest contractor measured this stand in September 2008. The highest Sitka spruce there was 20 m high.

Sitka spruce was used much in the period from 1950 until 1963 and then again after 1986 (Figure 4) (Pétursson, 1999).

The main usage of Sitka spruce has been as an outside ornamental tree, that is Christmas tree in squares and schools, it has also been chipped down and used in footpaths,

Damages

As described earlier there are not many problems with wind throws in spruce species in Icelandic forestry and root rot has not yet been found in Iceland. Snow damages can occur especially in younger stands and grazing damages by sheep.

There is one pest that is doing damage on Sitka spruce in Iceland and that is the green spruce aphid. The green spruce aphid *Elatobium abietinum* came to Iceland 1959 most likely with Christmas trees from Denmark (Halldórsson & Sverrisson, 1997).

The green spruce aphid is originally from Europe and Asia. It has spread to other parts of the world for instance America, New Zealand and Iceland (Carter & Halldórsson, 1998). The green spruce aphid attacks the older needles. It stings into the phloem to reach the phloem sap. The stinging is poisonous and the needle starts to become yellow but will eventually turn brown and fall off. Fully grown the green spruce aphid is 2mm in size. Distribution is done by flying individuals formed in the spring, in other time this aphid does not fly (Halldórsson & Sverrisson, 1997).

The life circle of the green spruce aphid is different in Iceland from other North Sea countries. The population peak is in the autumn in Iceland but in other North Sea countries, the population peak is in the spring and early summer. This resolves in more severe damages on Sitka spruce in Iceland than in other countries. In a study carried out in four countries around the North Sea, it was discovered that in Iceland there are only four natural enemies of the green spruce aphid. This is thought to influence the different time of population peak because the aphid does not have to adjust to the live circle of the enemy (Austarå, et.al, 1997). Temperature is a major factor in the population growth of the green spruce aphid. In an experiment of population growth with different temperature, the aphids from Iceland showed much more frost tolerance than aphids from England, but the growth rate of aphids from Iceland and N-Ireland where slower than aphids from Denmark and France at 15°C.

Since the green spruce aphid arrived in Iceland, there have been seven major outbreaks, 1964, 1977,1984, 1987, 1991, 1996 and 2003. The affect on the growth is clearly noticeable (Halldórsson et.al, 2006). Growth of affected trees is 50-80% less than of the growth of unaffected trees. The green spruce aphid seldom kills trees (Halldórsson et.al, 2003).

Other parasites on Sitka spruce are: the Spruce spite mite *Oligonychus ununguis* and the spruce shoot aphid *Cinaria pilicornis*, But these species are not doing much damage in the forest.

1.6 Similar studies

In his study from 2005 Fredrik Tengberg compares growing characteristics and volume production of Sitka spruce and Norway spruce. Tengberg measured permanent plots in Southern Sweden and had data not only for standing volumes but also for increment. One of his goals was to check if prognosis tools designed for Norway spruce could be used to predict the growth of Sitka spruce (Tengberg, 2005).

The results by Tengberg (2005) show that volume production of Sitka spruce is 14% higher than for Norway spruce in southern Sweden and if only the best stands are studied, the difference is 30 %.

Tengberg talks about that origin of plant material matters and he says that there is strong evidence that in the slowest growing? sitka spruce stands poor material has been used.

Tengberg used two prognosis tools for Norway spruce in Sweden to predict the growth ProdMod (Ekö 1985) and a height increment curves for spruce in north Sweden (Hägglund, 1972). The best results were given when both tools were used together. His study shows that the prognosis of volume was underestimated by 3%. This indicates that it should be possible to use the prognosis tools that are designed for Norway spruce to predict the volume growth of Sitka spruce. Sitka spruce showed more durable height increment than Norway spruce (Tengberg, 2005).

2 Materials and methods

2.1 Field measurements

Selection of stands

The climate in this area is rather moist and warm The average annual precipitation is 1051 mm and 181 days have +5°C or more in temperature, the elevation of the forest is 60-200m above sea level.

The forest at Stálpastaðir was established by planting stands of different species side by side. In this study stands with Sitka spruce and Norway spruce planted side by side was used. This design made it possible to find measurement pairs that have Sitka spruce and Norway spruce next to each other. In the beginning 10 measurement pairs where laid out on a map using Arc view 3.3 (Figure 8). Each pair had one stand with Norway spruce and one stand with Sitka spruce. The stands were planted the same year. The pairs were selected to find comparable growing conditions such as altitude, moisture and soil type. The stands within a pair are very close to each other, in most cases they are side by side.

To do this selection a database from the Icelandic Forest Service was used. This database contains all the necessary information needed for this selection, such as the size of the stands, tree species, year planted and if there was a mixture of species in the stand. It was not possible to measure all the pairs, 7 pairs were up to expectations and were measured.

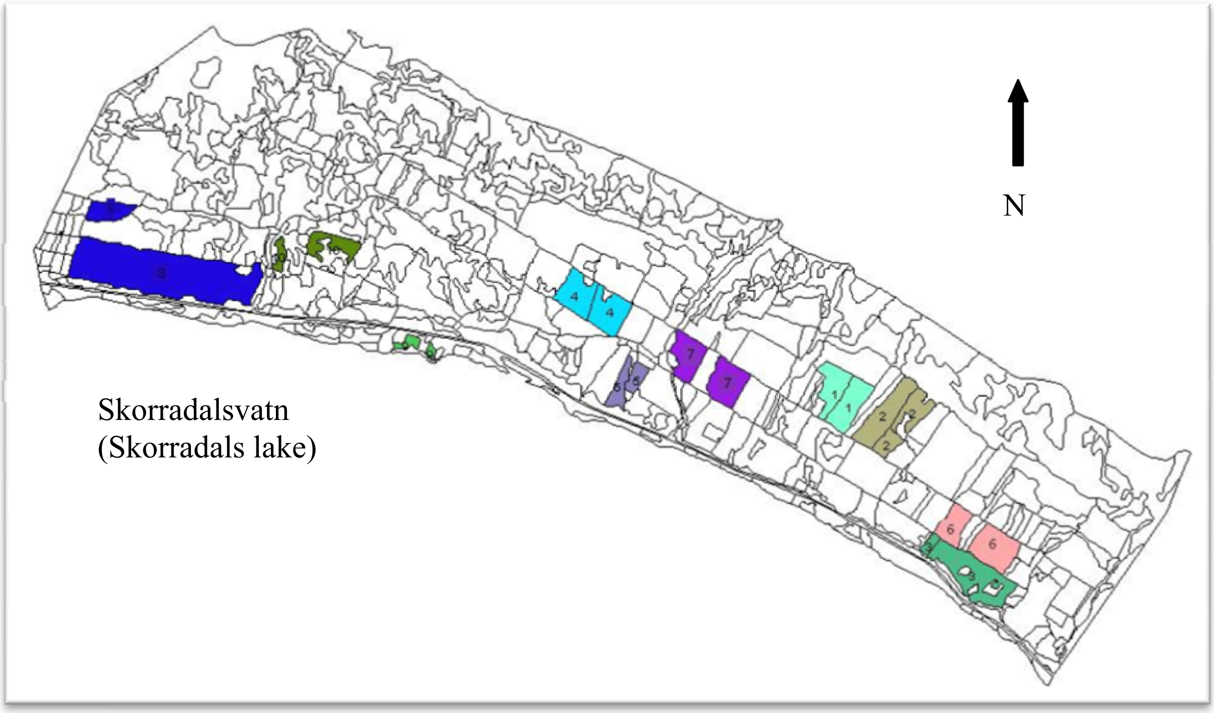


Figure 8. The pairs in this study the three pairs on the left were excluded but the others were measured.

Plot layout

In each stand, three measurement plots, each 200m^2 was used.. The plots was establiched along a line with 20 m distance between the centres of the plots. This line went straight up the hill. This was because the shape and size of the stands in most cases did not allow for other methods; most of the stands were not so wide and are approximately 100m long.

Unfortunately most of the stands that were measured were not thinned; therefore preparations had to be made before measuring. This preparation was mainly to prune most of the plots up to ca 2 meters height to make it possible to work there and see through the plot.

Figure 9. Measuring plot in unthinned Sitka spruce stand, the arrow points to the centre of the plot.

Table 3. Information about the stands the provenances, age and size of all the stand in the study

	Norway spruce			**Sitka spruce**		
Pair	**Provenance**	**Age years**	**Size ha^{-1}**	**Provenance**	**Age years**	**Size ha^{-1}**
1	N Helgeland	46	0,6	Seward	46	0,7
2	S Helgeland	48	0,9	Cordova	48	0,8
3	Otteröy	52	0,1	Mcleod Lawing	52	1,3
4	Y Namdalen	49	0,7	Cordova	49	0,7
5	Helgeland	50	0,3	Seward	50	0,2
6	Fellingfors	52	0,5	Mcleod Seward	52	0,9
7	Helgeland	55	0,7	point Packenham	55	0,6

As seen in Table 3 the age of the pairs varies from 46 years to 55 years. In general, the area of the stands is about equal except in pair 3. Provenances are different and sometimes there are two provenances in one stand.

Figure 10. The same plot as in Figure 9 but after pruning to make it possible to work there.

Figures 9 and 10 show that these measurement plots did not always have the best conditions for measuring since they were dense, not thinned, and sometimes very steep.

The measurements

Each measuring plot was marked with a yellow pin. The size of each plot was 200 m^2. A pole with 7.98 m long string was put in the middle of the plot; this string is used to form the measurement plot. If more than half the width of a stem was inside the circle the tree was included in the measurement but if less than half of the stem was inside the circle the tree was excluded.

The first tree was always located to the right side of the centre when facing up the hill and as far away from the centre as possible. The first tree was marked with the number 1 to make it easy to know where to stop. From the first tree, measurements were continued counter clockwise and trees were measured as the string touched them. Each tree that was height measured was marked.

Diameter in breast height (DBH) of all trees in plot was measured with a caliper, it was always cross measured and was measured standing higher in the slope than the tree, with the caliper pointing to the middle of the plot and then in 90° to that direction. Trees less than 5 centimetres in diameter were excluded.

In some stands, especially in the Norway spruce stands, Christmas tree cuttings have been done. These cuttings were performed in the way that the tree was not cut near the ground; a part of the stem and some branches were left to grow. These trees grew up as multi stem trees. In some stands there were many of these multi stem trees. All stems thicker than 5 cm were measured but only the height of the highest top if there was height measurement on such tree.

The height measurements were done with Suunto PM-5 height measurement equipment The method to choose which trees to measure was as follows; the first and then the fifth tree in each diameter class was height measured and also the dominant height tree in each plot. Each diameter class reached over 10 centimetres. The diameter classes were 5-10 cm; 11-20 cm; 21-30 cm and 31-40 cm. The diameter class system was continued out for each stand i.e. selection of sample trees continues through all the plots in one stand.

The height of the dominant height tree (the tree with largest diameter) in each plot was measured. The dominant tree is not necessarily the highest tree, if there were some higher trees in the stands also the tree height of the highest tree was measured. .

Were there had been some cutting done the diameter of the stumps was measured with the calliper. The stumps where not cross-measured but they were all measured with the calliper pointing to the middle of the plot.

2.2 Calculations

The volume for individual trees was calculated with functions for Iceland, prepared by Arnór Snorrason and Stefán Freyr Einarsson in 2006 (Snorrason & Einarsson, 2006).

- For Norway spruce: Volume = $0{,}1299*dbh^{1{,}6834}*h^{0{,}8598}$
- For Sitka spruce: Volume = $0{,}0739*dbh^{1{,}7508}*h^{1{,}0228}$

Dbh = diameter at breast height, in cm
H = height in meter
The volume result from these formulas is in dm^3 (“litres”).

To calculate the volume of the standing trees that were not height measured a secondary volume functions for each species and for each stand was constructed, using multiple regressions .

$$Volume = a + b*dbh + c*dbh^2$$

the constants a, b and c are found by using the regression

To calculate the volume of the felled trees diameter at breast height was calculated by using functions by Edgren and Nylinder (1955). First the form code (Edgren and Nylindeer,1955) was calculated by using height and diameter of standing trees. With the form code, diameter at breast height for felled trees was calculated from the stump diameter at ground level. Finally, the volume of the felled trees was calculated with the same secondary volume function as the standing trees.

Site index (SI) is used to indicate the site quality from dominant height. Site index for Norway spruce was calculated using functions for north Sweden, (Hägglund,1972). Site index for Sitka spruce was calculated using the same function.

A t-test was performed on the results.

3. Result

Number of stems

The number of stems are usually higher for Norway spruce than Sitka spruce (table 4). The average stem number for Norway spruce are 3188 trees, and for Sitka spruce it is 2629 trees/ha, the difference is 559 trees/ha and relative difference is 17,5%.

Among not thinned stands, the lowest number of stems for Norway spruce is in stand 5 with 2283 trees/ha, the lowest number of stems for Sitka spruce is in stand 6 with 1900 trees.

The lowest total number of stems for Norway spruce is in stand number 3 with 2175 trees/ha and for Sitka spruce stand number 6 has the lowest value with 1933 trees/ha.

The highest number of stems is in pair 1, there Norway spruce has 4733 trees/ha and Sitka spruce has 4067 trees/ha (Table 4).

Table 4. Number of trees per hectare for both species standing, felled and total Density trees/ha

	Norway spruce			Sitka spruce		
Pair	**standing**	**felled**	**total**	**standing**	**felled**	**total**
1	4567	167	4733	4067	0	4067
2	3050	350	3400	2600	0	2600
3	1000	1175	2175	2270	910	3180
4	3550	133	3683	3300	717	4017
5	2283	200	2483	2767	217	2983
6	3983	83	4067	1900	33	1933
7	3883	367	4250	1500	2133	3633
Average	3188	354	3542	2629	573	3202

Dominant height and Site index

Dominant height and Site indexes are higher for Sitka spruce than for Norway spruce in all stands, when using site index curves for spruce. Average difference in dominant height is, Norway spruce 10,3m and for Sitka spruce 14,8m this gives difference of 4,5m and relative difference 44,4%. Average site index Norway spruce 192 and Sitka spruce 243 difference is 51,1 and relative difference of 27,1% (Table 5).

Table 5. Dominant height (Hdom) and site index (SI) for both species and the difference between the species.

		Norway spruce		Sitka spruce					
Pair	Age	Hdom, m	SI, m	Hdom, m	SI, m	Diff Hdom, m	Diff Hdom,, %	Diff SI, m	Diff SI, , %
1	46	8,8	18,4	11,6	22,1	2,8	32	3,7	20
2	48	10,2	19,8	16,2	26,5	5,9	57	6,7	33
3	52	10,6	19,2	17,2	26,4	6,6	61	7,2	37
4	49	8,5	17,1	14,3	24,2	5,8	68	7,1	41
5	50	11,7	21,0	12,4	21,8	0,8	6	0,8	3
6	52	11,0	19,6	14,5	23,6	3,6	32	4,0	20
7	55	11,5	19,4	17,4	25,7	5,9	51	6,3	32
Average	50,3	10,3	19,2	14,8	24,3	4,5	44	51,1	27

For both the dominant height and the site index has pair number 4 the biggest difference 5,8m and relative difference 68,6%. For site index the largest difference is 7,1m and relative difference 41%.

The smallest difference is in pair number 5; 0,8m and relative difference of 6,4%. For the site index the smallest difference is 8 and relative difference 3,8%.

The highest Dominant height is in Sitka stand number 7; 17,4m and the lowest dominant height is in Norway spruce stand number 4; 8,5m.

The highest value for site index is found in Sitka spruce stand number 2; 26,5m and the lowest value is in Norway spruce stand number 4; 17,1m.

Basal area

The basal area is higher for Sitka spruce than Norway spruce in all stands. In average values for standing basal area is Norway spruce 40,4 m^2 /ha and Sitka spruce 55,2m^2/ha this gives difference of 14,8m^2/ha and relative difference of 44,0%.

The highest value for standing basal area are found in Sitka spruce stand number 5; 68,6 m^2/ha and the lowest value is in Norway spruce stand number 3 it has basal area of 20,9 m^2/ha.

The difference for standing basal area is lowest in pair 8 only 2,1 m^2/ha and relative difference of 4,0 %.

The highest relative difference is in pair 3 with difference of 25 m^2/ha and relative difference of 119,7% (Table 6).

Table 6. The standing basal area, m^2/ha for both species and the difference between them.

Pair	Norway spruce Basal area, m2/ha	Sitka spruce Basal area, m2/ha	diff	rel diff
1	38,4	49,1	10,8	28,0
2	34,6	52,8	18,2	52,6
3	20,9	45,8	25,0	119,7
4	42,7	50,0	7,3	17,0
5	46,2	68,6	22,4	48,4
7	47,8	65,9	18,1	37,9
8	52,4	54,4	2,1	4,0
Average	40,4	55,2	14,8	44,0

Volume yield and mean annual increment.

For all pairs, the standing volume is higher for Sitka spruce than for Norway spruce. In average the standing volume for Norway spruce is 196,3 m3 and for Sitka spruce 357,4 m3. The difference varies from 96 m^3/ha to 209,6 m^3/ha, and is in average 161,1 m3(Table 7).

The biggest relative difference in standing volume yield is in pair number 3 were Sitka spruce has 209 m^3/ha higher volume yield and relative difference is 201%.

The smallest relative difference is in pair number 4 were the difference for standing volume is 96,0 m^3/ha and relative difference 49%.

The total production, (standing volume + felled volume) is higher for Sitka spruce than for Norway spruce in all pairs. The average for total volume yield is for Norway spruce 216,3m^3/ha and Sitka spruce 407,3m^3/ha, this gives difference of 191 m^3/ha and relative difference of 86,9%.

The biggest difference for total volume yield is in pair no 7; 365, 63 m^3/ha, which gives relative difference of 133, 6 %.

The smallest difference for total volume yield is in pair 1; 98,1m^3/ha, which gives relative difference of 57,9%.

Table 7. Standing volume, m^3/ha estimated felled volume and the total volume and the difference and relative difference between them for all stands in the study

	Norway spruce			Sitka spruce						
Pair	**standing volume** m^3/ha	**felled volume** m^3/ha	**total volume** m^3 /ha	**standing volume** m^3 /ha	**felled volume** m^3 /ha	**total volume** m^3 /ha	**Diff standing** m^3 /ha	**rel diff standing %**	**Diff total** m^3 /ha	**rel diff total %**
1	162,5	7,1	169,5	267,7	0,0	267,7	105,2	64,7	98,1	58
2	153,5	8,5	162,0	329,5	0,0	329,5	176,1	114,7	167,5	103
3	103,8	86,5	190,3	312,9	69,5	382,3	209,0	201,3	192,0	101
4	196,0	3,2	199,2	292,0	25,8	317,9	96,0	49,0	118,7	60
5	261,1	14,8	275,9	443,3	14,8	458,1	182,2	69,8	182,3	66
6	237,4	6,3	243,7	447,0	9,2	456,2	209,6	88,3	212,5	87
7	260,2	13,5	273,7	409,5	229,9	639,3	149,2	57,4	365,6	134
Average	196,3	20,0	216,3	357,4	49,9	407,3	161,1	92,2	191,0	87

Mean annual increment

The results for the mean annual increment (MAI) shows the same relative difference as for volume yield. Sitka spruce has higher increment than Norway spruce in all pairs. For Norway spruce MAI is in average 4,3 m3 and for Sitka spruce MAI is in average 8,0 m3.

The average difference for total MAI at standing age is 3,7 m^3/ha, year that gives relative difference of 86,9%.

The highest value for total MAI at standing age is in Sitka stand number 7; 11,6m^3/ha, year and the lowest is in Norway spruce stand number 2; 3,4m^3/ha, year.

The biggest difference for total MAI at standing age is in pair 7; 6,6 m^3/ha, year and relative difference of 133.6% .

The smallest difference in total MAI at standing age is in pair 1; 2,1 m^3/ha, year with relative difference of 57,9% (Table 8).

Table 8. The mean annual increment (MAI) for all stands; standing, felled and total at standing age and the difference between them.

		Norway spruce	Sitka spruce	Difference	
Pair	**Age**	**MAI m^3/ha,year**	**MAI m^3/ha,year**	**diff total m^3/ha, year**	**rel diff total, %**
1	46	3,7	5,8	2,1	57,9
2	48	3,4	6,9	3,5	103,4
3	52	3,7	7,4	3,7	100,9
4	49	4,1	6,5	2,4	59,6
5	50	5,5	9,2	3,6	66,1
6	52	4,7	8,8	4,1	87,2
7	55	5,0	11,6	6,6	133,6
Average		4,3	8,0	3,7	86,9

Statistical analysis

A t-test was made on the results and it gave the result a very good credibility. The t for volume was 0,000277, for MAI t was 0,000111 and for basal area, it was 0,000226.

4. Discussion:

It is known from earlier studies that Sitka spruce often grows better than Norway spruce, e.g. Tengberg (2005). Therefore, higher values for Sitka spruce are expected.

In the result, the difference between the species for standing volume and mean annual increment is big. In all examined pairs of trees species measured in this study the volume production was higher in Sitka spruce compared to Norway spruce. For standing volume the difference is 161,1m^3/ha and or 92,2% and for total volume yield, the difference is 191,0 m^3/ha or 86,9% in favour of Sitka spruce.

Volume yield expressed as MAI are in average 4,3 for Norway spruce and 8,0 m3 for Sitka spruce.
The values for basal area are also higher for Sitka spruce than for Norway spruce the difference is 14,8 m^2ha^{-1} which gives relative difference of 44%.

All these results show that Sitka spruce grows much better than Norway spruce in this region. In Figure 11 the relationship between MAI for both species is shown

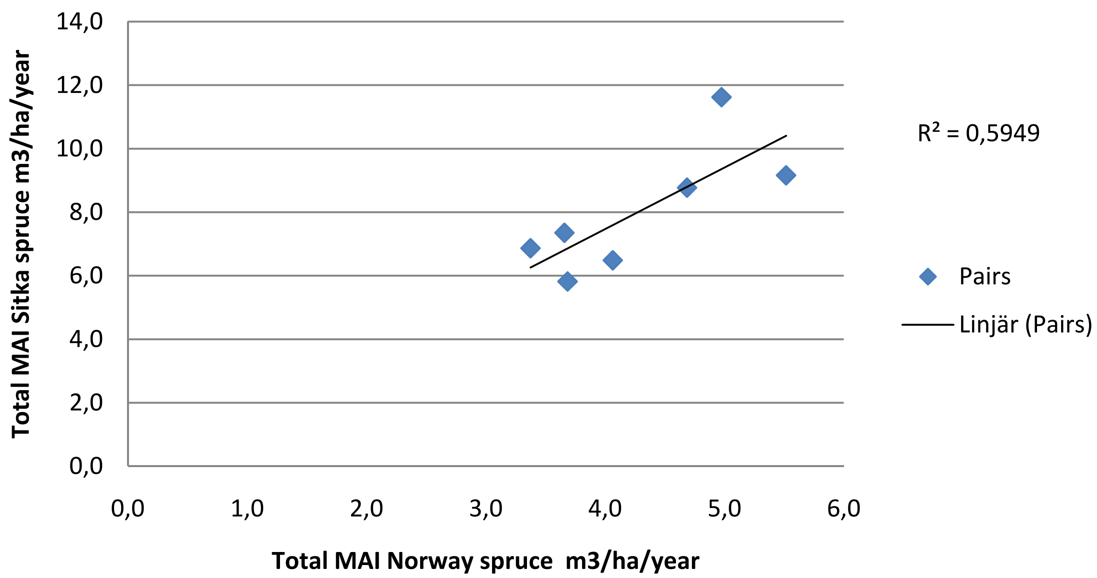


Figure 11. Relationship between total MAI at standing age for Sitka spruce and Norway spruce.

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Reasons for higher yield in Sitka spruce than in Norway spruce

There can be many reasons why Sitka spruce produces more than Norway spruce in this study. . One is the climate, as mentuned the climate in this region is oceanic with annual precipitation about 1051 mm and 181 days with more than +5°C per year. Sitka spruce is much better adapted to such climate than Norway spruce. Another factor can be the soil but there is no data available about that.

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Comparison with Tengbergs work

Both studies show higher yield for Sitka spruce than for Norway spruce and that is similar to other studies on the same matter. Tengbergs results show less difference between Norway spruce than Sitka spruce than this study. Tengberg has in average 14% higher yield for Sitka spruce than for Norway spruce and 30% if only the best stands are used. This study has 92,2% for standing volume yield and 86,9% for total volume yield. This is a very big difference between these two studies.

Conditions in Southern Sweden are different from Iceland. The climate in Skorradalur is oceanic with annual precipitation of about 1051 but in Sweden the precipitation is less or about 670 mm per year for example in Gothenburg. The growing period is longer and the summers are warmer in Sweden and the winters are not as harsh as in Iceland. In both countries the stands are located where there is oceanic climate. Norway spruce is a natural species in Sweden even though it is introduced in southern Sweden. However, Sitka spruce is an exotic tree species in Sweden. Both species are exotic in Iceland.

In both studies there are indications that the provenance influences the growth of the species for instance is Tengberg positive that in the stands were the yields of Sitka spruce is lower than for Norway spruce the provenances of Sitka spruce isn't the right one for the area.

In this study it is indicated that the slow growth of Norway spruce has something to do with the northerly origin, in that way these two studies are similar.

Possible biases

There is always a possibility to make a mistake in the measurements and calculations that can lead to wrong results and human mistakes are often the cause of bias and it can also be so in this study.

The measuring pairs are not the same age the difference is nine years in total (Table 3). This age difference makes it impossible to compare within the species. All the stands are older than 45 years old, which means that they have gained some maturity and are not facing the problems of a young stand any more.

The location of the stand can make a difference here. The nutrients leak down the hill this means that stands that are situated lower in the hill will have more nutrients than stands that are higher. The fact that this forest is in a hill site gives the trees a better growth than if it was on flat ground because of the nutrients leak and shelter. This fact is beneficial for both species. In this study each pair have equal age and are growing with equal growing conditions side by side. Most probably different site conditions have no effect on the result.

In some stands were Christmas trees have been cut the stump with the lowest branches was left and these branches grew up as leading shots ending up in a rather low multi stemmed tree. This was more common in Norway spruce than in Sitka spruce. There is a possibility that the multi stem trees in the Norway spruce stands could cause bias in the calculations. But the total number of stems are quite equal in sitka spruce and Norway spruce. Probably this has only a small or no affect on the result.

Another possible reason for bias is the estimation of the volume of the felled trees. It can be that the calculated form code is wrong, and it is possible that the shape of the stump can give wrong results. The stumps in this area are low so that the root formation can interrupt the measurement so that the tree seems thicker than it is; this can lead to over estimation of the dbh and make bias in the calculation from the dbh such as basal area, volume and MAI.

In Figure 13 the difference for standing volume yield and total volume yield is displayed, it also indicate the volume of felled trees. Volume for the felled trees was calculated from estimated diameter at breast height. In addition, the height at time of felling was unknown and the secondary volume functions based on the standing volume was used. Therefore, the volume of felled trees is most probably overestimated. Figure 12 shows clearly that these errors cannot change the main result of this study. Standing volume for Sitka spruce is higher than total volume (standing+felled) for Norway spruce in all pairs and in average In average standing volume of sitka spruce is 65% higher thantotal volume for Norway spruce.

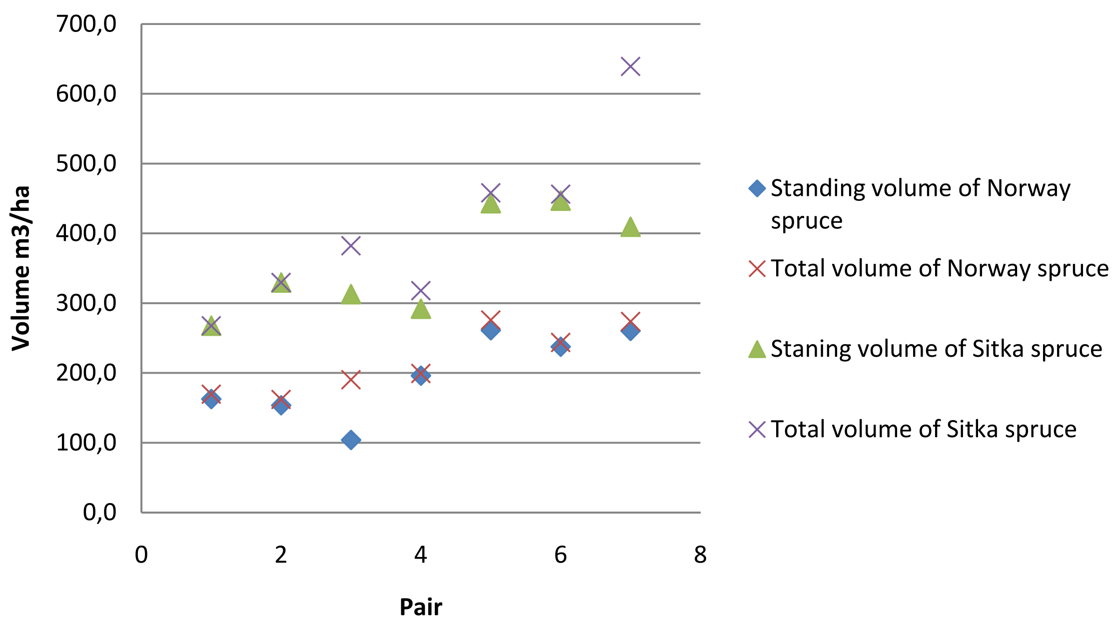

Figure 12. Standing and total volume of both species

Dominant height trees are usually wolf trees they have very thick stems and big branches but are not always very high. The fact that the dominant height trees are not necessarily the highest tree effects the estimation of the site index, because the site index is estimated from the dominant height. The fact that the stands were usually not thinned makes it much more likely to have such trees as the dominant trees, than if the stands had been thinned and the wolf trees removed. This difference in height of the dominant height trees and the highest trees are shown in Figure 13. For site classification with height development curves this can have an effect, but in the comparison of volume production between species with the methods used in this study, it has no influence.

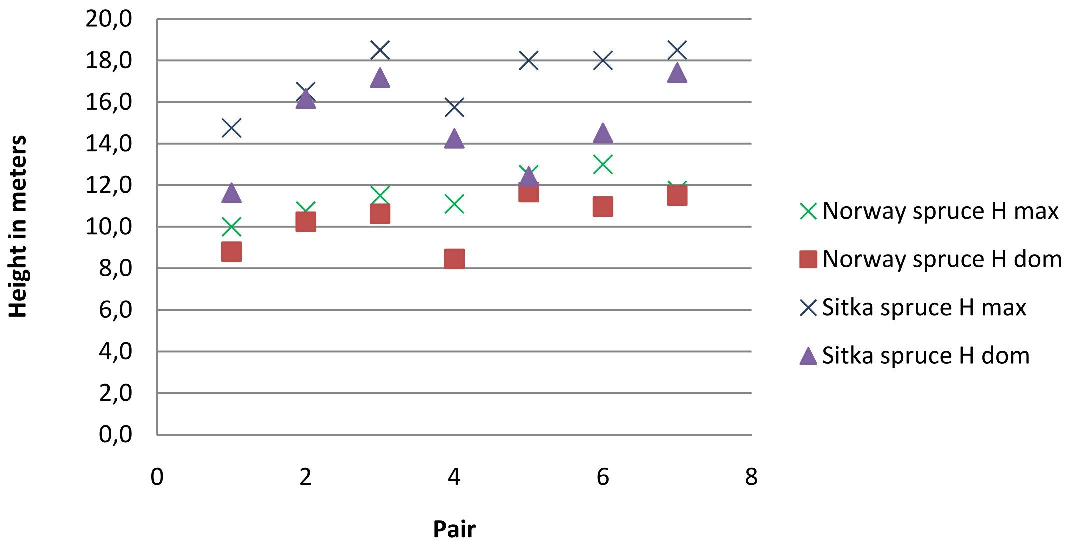

Figure 13. Shows the dominant height and the maximum height for both species. notice the difference in dominant height and maximum height.

Other things that can influence the result

The initial density is not known, it is not possible to tell about survival rate for the stands. However, older forest workers in Iceland say that planting density was high in those years when this forest was established. The aim for this high planting density was to let the plants shelter each other and then thin the stand when the seedlings had reached safe height but these thinnings were usually not performed. This has probably no or very little influence of the results as that initial spacing was about the same in Norway spruce and Sitka spruce.

The difference is not as big for total number of stems. The Norway spruce has 3542 trees/ha and the Sitka spruce has 3202 trees/ha. This gives a difference of 340 trees/ha and relative difference of 9,6%.

In Iceland, the dominant height trees are not necessary the highest trees in the stand. This is well known to Icelandic foresters. In stands that have not been thinned, it is most likely that the thickest trees are wolf trees. It is probably by lack of shelter in the young age that can lead to more diameter growth instead of height growth (more carrot shape). These factors have probably no or very little effect on the results.

Trees that are less than 5 cm in diameter are not measured, in a forest of this age these trees are usually dead or dying and their volume is too small to affect the result. Those trees are for this reason not relevant for the study and are therefore excluded from the measurement.

From the discussion above it is obvious that many elements have to be considered when selecting tree species for forestry, one of them is the origin of the seeds. Other elements that can influence the growth are location in the land and soil condition as mentioned earlier in this chapter. The results in this study show that the conditions in this region are better for the Sitka spruce than the Norway spruce. Similar results can be expected in other parts of the country where the conditions are similar; it can refer to most parts of the west and south-west of Iceland.

Provenances

Most of the stands in the pairs have similar size that is good for comparison. It should give the same edge effect for the stands. Pair 3 is the only pair that has a big difference in size of the stands and that can influence the comparison (Table 3).

The origin of the two spruce species studied is quite different. The Sitka spruce is coming from the area of Prince Williams Bay in Alaska. The Norway spruce comes from the area of North Trondelag in Norway that is North of Trondheim

In Table 9 the location of the Norway spruce provenances are detailed. They are all quite northerly and some of them are far away from the ocean. Most of the Norway spruce provenances are from above 65°N.

Table 9. The coordinates of the Norway spruce provenances.

Provenance	latitude	longitude
N-Helgeland	65°55´N	13°15´E
S-Helgeland	65°5´N	12°25´E
Helgeland	From 65°N – 66°45´N	
Y- Namdalen	64°30´N	11°30´E
Fellingfors	65°35´N	13°25´E
Otteröy	64°31´N	11°18´E

The provenance Helgeland refers to a very large area so it is not possible to say with any certainty were the seeds were collected.

Table 10. The coordinates of the Sitka spruce provenances.

Provenance	Latitude	Longitude
Point Pakenham	61°00´N	148°04´W
Lawing	60°24´N	149°23´W
Seward	60°06´N	149°26´W
Cordova	60°32´N	145°45´W
McLeod	59°52´N	147°23´W

As seen in Table 10 the Sitka spruce provenances are located around Prince Williams Bay. Most of them are located near the ocean. The provenance Lawing is furthest away from the ocean and has most likely the highest altitude.

In a resent measuring of a Norway spruce provenance research within the Stálpastaðir forest area, show that the provenance of Norway spruce that grows best is from Baden in Germany and the worst growth is provenance from Rana in northern Norway close to the arctic circle. In general, the more northerly provenances have less growth and yield than the southerly ones (Benedikz & Heiðarsson, 2007).

Provenances from inland areas are not as well adapted to oceanic climate as provenances that are closer to the ocean; this is likely to be the same for altitude the higher above sea level the less adapted to lowland conditions. In this study, no stands are higher than 200 m above sea level.

The climate in southern and western part of Iceland is oceanic. Oceanic climate have wet and rather mild winters and mild summers, which is probably more suitable for Sitka spruce than Norway spruce. This is probably one of many reasons for the big difference. The fact that the Norway spruce provenances are from further north than the Sitka spruce, is likely to influence the results, the northerly provenances are used to shorter growing season and do not use the summer as well as the more southerly provenances. In my opinion, this is one of the bigger factors for this big difference in growth and yield. It is a good possibility that with a good selection of provenance of Norway spruce the difference between Sitka spruce and Norway spruce could be reduced. That is if there is a provenance of Norway spruce with better growth and yields than are already in use. The reason for the usage of these northerly provenances in Iceland is that it was the general believe that northerly provenances were hardier than the southerly ones and therefore better for the harsh condition in Iceland.

5. Conclusions

The conclusion from this study is that there is a very big difference between the two species in favour of Sitka spruce. Sitka spruce is producing in average 87% more than Norway spruce. This difference can be explained with many reasons and it is not any one element that causes this difference but combination of several elements. The conditions in Skorradalur are clearly better for Sitka spruce than for Norway spruce. The oceanic climate with rather high precipitation and rather mild winters is better for Sitka spruce than Norway spruce. The selection of the correct provenance can be crucial for forestry and that can be seen clearly in this study, were there is a big difference within the species as between them. I think that better provenances for Norway spruce can be found and it is possible to promote the species by finding the right provenances for the area.

It is important for the future in Icelandic forestry to know which species and which provenances to use in each area (quarter) of the country and researches in that field are needed. If the best provenances and species for each quarter are used the growth and yield of the forests will be much better and better economy will follow. This is extremely important now when Icelandic forestry and forest industry is developing faster than before. This result shows that the conditions in Iceland are not bad for growing Sitka spruce and it can be possible to find the right provenance for Norway spruce.

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