Poplar for biodiversity?

Comparison of lichen communities in stands of Balsam poplar, Hybrid larch, Silver birch and Norway spruce.

Ewa Zuzanna Jastrzębska




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Ewa Zuzanna Jastrzębska

Supervisor:	Henrik Böhlenius, SLU, Southern Swedish Forest Research Centre
Assistant supervisor:	Lisa Petersson, SLU, Southern Swedish Forest Research Centre
Examiner:	Jörg Brunet, SLU, Southern Swedish Forest Research Centre

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Swedish University of Agricultural Sciences
Faculty of Forest Science
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Abstract

Due to increasing interest in the use of non-native tree species, more knowledge is needed concerning their effects on biodiversity. In this context, epiphytic lichens were investigated in two stands of non-native tree species (*Larix*×*eurolepis* and *Populus trichocarpa*) and two stands of native tree species (*Picea abies* and *Betula pendula*) in a field experiment in southern Sweden. The trunks in the stands were examined separately for northern and southern side of the tree trunk. The presence of all types of lichen (crustose, foliose and fruticose) species were registered.

Twenty-two lichen species in total were found in the experimental sites; six in *P. abies* stand, seven in *B. pendula* stand, nine in *L.*×*eurolepis* stand and eighteen in *P. trichocarpa* stand. Most of the lichen species are common in Sweden. Although one red-listed lichen species, *Alyxoria ochrocheila* was found. The status of this lichen is near threatened (NT).

The non-metric multidimensional scaling (NMDS) had been used for displaying the diversity of lichen communities. The study showed the highest lichen community diversity and species richness in the *P. trichocarpa* stand. The only one red-listed lichen species, *A. ochrocheila* was also found in this stand. The other non-native tree species stand (*L.*×*eurolepis*) showed higher diversity and species richness than both stands of native tree species. The less lichen diverse and the poorest in lichens species was the *P. abies* stand.

The diameter breast height was not significant for lichen richness in this study. Neither was the side of the tree on which the lichens were found.

Investigated non-native tree species seem to have potential to increase biodiversity in production stands. Considering the bark complexity, fast growth and stand architecture, species like poplar may support ecological functions similar to those provided by great-dimension, old trees like oaks. It is recommended to continue the study in other parts of Sweden.

Keywords: Poplar, *Populus trichocarpa*, lichen, biodiversity, epiphytic lichen, Norway spruce, Hybrid larch, Silver birch, Sweden

Abstrakt

Ze względu na rosnące zainteresowanie uprawą nierodzimych gatunków drzew oraz rosnące w związku z tym znaczenie braku wiedzy z zakresu różnorodności biologicznej w drzewostanach złożonych z nierodzimych gatunków drzew, przeprowadzono badanie różnorodności biologicznej. Zbadane zostały dwa drzewostany złożone z gatunków nierodzimych (tu: *Larix×eurolepis* i *Populus trichocarpa*) i dwa drzewostany złożone z gatunków rodzimych (tu: *Picea abies, Betula pendula*) dla Szwecji.

Do oceny bioróżnorodności wykonano inwentaryzację epifitycznych porostów. Pnie ze wszystkich drzewostanów zostały sprawdzone po ich północnej i południowej strony. Wszystkie znalezione gatunki zostały odnotowane. W badaniach nie zastosowano metod ilościowych.

Znaleziono w sumie dwadzieścia dwa różne gatunki porostów. Sześć gatunków porostów wystąpiło w drzewostanie *P. abies*, siedem w drzewostanie *B. pendula*, dziewięć w drzewostanie *L.×eurolepis* i osiemnaście w drzewostanie *P. trichocarpa*. Większość z odnotowanych gatunków porostów jest w Szwecji powszechna, jednak znaleziono również jeden gatunek opisany na czerwonej liście jako near threatened (NT).

Wykorzystano metodę niemetrycznego skalowania wielowymiarowego (non-metric multidimensional scaling - NMDS) do przedstawienia zróżnicowania zbiorowisk porostów. Studia wykazały dużo większą różnorodność między zespołami porostów w drzewostanie *P. trichocarpa*. W drzewostane *P. trichocarpa* odnotowano również dużo większe bogactwo gatunkowe porostów niż w pozostałych drzewostanach. Drugi z nierodzimych gatunków, *L.×eurolepis* wykazał się większym bogactwem gatunków porostów niż drzewostany złożone z *P. abies* i *B. pendula*. Najbardziej ubogi w gatunki porostów i najmniej zróżnicowane zespoły porostów przedstawił drzewostan *P. abies*. Pierśnice drzew pomierzonych w tych badaniach nie miały znaczenia dla odnotowanego bogactwa porostów na poszczególnych drzewach. Podobnie zależności nie wykazała też strona pnia na której znajdowano porosty (północna lub południowa).

Zbadane drzewostany złożone z gatunków drzew nierodzimych w Szwecji, w tych studiach udowodniły wzbogacać tamtejszą różnorodność biologiczną pod względem porostów. Biorąc pod uwagę złożoną strukturę kory, szybki wzrost i urozmaiconą strukturę i warunki świetlne drzewostanu, gatunki takie jak *Populus trichocarpa* mogą, przynajmniej w przebadanym wąskim zakresie, wspomagać ekologiczne funkcje wypełniane zwykle przez znacznie starsze drzewa gatunków szlachetnych (jak *Quercus spp.*). Rekomenduje się dalsze prowadzenie badań w tym kierunku, szczególnie w innych lokalizacjach w Szwecji jak i z użyciem metod ilościowych.

Keywords: Populus trichocarpa, porosty, bioróżnorodność, różnorodność biologiczna, epifity, porosty epifityczne, Szwecja

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Abbreviations

DBH	Diameter at breast height
FGTS	Fast growing tree species
NMDS	Non-metric multidimensional scaling
SLU	Swedish University of Agricultural Sciences

1. Introduction

When the climate changes the forest is changing. Urgent need for fossil fuel replacement, the importance of carbon sequestration and rapid weather (e.g. storms (Gardiner et al. 2020) which represents a great hazard for conventional forestry (Lidskog and Sjödin 2016, Felton et al. 2010), all these factors push us to find better ways to manage the forests. Aside from sustainable management, the forest sector is facing another challenge – to fill a growing demand for timber and pulp. All above may explain increasing interest in use of fast-growing tree species. Although non-native species show many advantages in terms of shortening rotation and biomass production (Tullus et al. 2012, Larsson-Stern 2003), we still do not know much about their impact on the environment.

Birch and Spruce

Together with Scots pine *Pinus sylvestris,* Norway spruce *Picea abies* and two birch species, Silver birch *Betula pendula* and Downy birch *Betula pubescens,* are the most common tree species in Sweden (SFA 2014). *P. abies* is the most common dominant tree in southern Sweden. It is a secondary tree species and can tolerate shadow quite good, especially in its young years. The rotation age is usually from 50 to 70 years. It is the mostly chosen species for planting on clear-cuts. *Betula* is the most common deciduous tree species in Sweden. *Betula* is a pioneer tree, rather short-lived and very light-demanding. It occurs very often in clear-cuts as natural regeneration, forming, not necessarily wanted, admixture. *B. pendula* and *B. pubescens* are closely related and it is common practice in forestry to not differentiate them.

Larch

Hybrid larch *Larix×eurolepis* is a cross of two larch species: European larch *Larix decidua* and Japanese larch *Larix kaempferi*. Hybridization between *L. decidua* and *L. kaempferi* was first observed in Scotland in 1901. It is hard to distinguish *L.×eurolepis* from one of its parents. *Larix* is a dioicous species. Hybridisation seed orchard for *L.×eurolepis* seeds is made of one mother clone and several father clones, which reduces probability of producing seeds of pure *L. decidua* or *L. kaempferi*. Due to a Japanese parent, *L.×eurolepis* is more resistant to larch cancer (Larsson-Stern 2003).

Larix×eurolepis is a very light-demanding species (Larsson-Stern 2003). The growth is rapid and peaks rather early; the biggest simulated MAI was 13 m3/ha in a 35-year-old stand (Larsson-Stern 2003). Rotation for large dimension quality timber in larch is at least 80 years, but larch can also be cultivated in much shorter rotation, 30-50 years (Larsson-Stern 2003).

In Sweden, only Siberian larch *Larix sibirica*, due to fossil findings (Kullman 1998) is considered native and can be used in forestry without restrictions. *L. decidua* and *L. kaempferi* and their hybrid are non-native, and plantations larger than 0,5 ha must be reported to the County Board (Larsson-Stern 2003). In southern Sweden *Larix×eurolepis* shows good growth in sites classified as intermediate for Norway spruce (Ekö, Larsson-Stern, and Albrektson 2004). Due to increased soil fertility, on former arable lands, larch tends to show stronger growth but lower stem quality (Larsson-Stern n.d.). It is suitable for pruning and can be used as a shelter for other deciduous tree species. Therefore, *Larix×eurolepis* is the most commonly used larch in southern Swedish forestry (Larsson-Stern 2003).

Poplar

Besides aspen *Populus tremula*, there are no other species of poplars native to Sweden. In practical plantations with hybrid poplars, hybrids between different species are usually planted were one of the parents is Balsam poplar *Populus trichocarpa* (Karačić 2005). In contrast to hybrid aspen of which parent are *Populus tremula* and *P. tremuloides* (Tullus et al. 2012). *P. trichocarpa* originates from North America and is the northernmost hardwood in Canada and Alaska. In its natural range, it grows the best in river flood plains but occurs also in uplands (Benomar et al. 2013). It is a fast-growing tree species with a rather short lifespan, although some trees are reaching 200 years (Zasada & Phipps 1990). In its natural habitat *P. trichocarpa* is a pioneer species which steps aside after 50-75 year of its dominance (Zasada & Phipps 1990). *P.trichocarpa* is a dioecious tree; ready to reproduce already at the age of 8 to 10 years, and is producing seeds yearly after that (Zasada & Phipps 1990). Apart from seeds, *P. trichocarpa* has a great capability for vegetative reproduction, which can be planted from cuttings or cultivated in coppice (Olson et al. 2013). *P. trichocarpa* is growing to astounding size in a short time. It can reach 90 to 180 cm in diameter at breast height and 23 to 30 m height (Karacic et al., 2003, Karačić, 2005, Zasada & Phipps 1990).

Like other non-native tree species and hybrids, *P. trichocarpa*, cannot be grown in Swedish forests on regular bases, according to the Swedish Forestry Act (Skogsvårdslagen). However, in arable sites it can be cultivated as an energy crop (Tullus et al. 2012). In Sweden there are 400 000 ha of agricultural land that can be used for fast growing trees plantation like Poplars without interfering with food production. In addition to this there are 1-2 million ha of agricultural land planted with crop that can in the near future be harvested and there are 2-2,5 million ha of forest land (depending on site index) that could be used for growing poplars (Larsson et al. 2008). Thus, there is a great potential for using poplars as a source for increasing wood production. However, we do not have much knowledge of the biological value of Poplars in Swedish forests.

According to (Tullus et al. 2012) *Populus spp.* plantation are showing more divers understory vegetation in compared to arable land in general, and species composition in intensively managed stands of *Populus spp.* includes few rare or endangered species. In a French inventory of poplar plantations of various ages and locations, species richness, Shannon index and equitability index of ground beetles were higher than in compared broad-leaved forest and cereal fields (Berthelot et al. 2005). On the other hand, a Polish study compared ground beetles richness in old poplar plantation (60 years old) to arable fields. The species richness proved to be lower in poplar plantation. Moreover, authors conclude that poplars plantation are not enhancing regional species diversity and that poplar plantations are not reaching a species diversity of at least semi-natural forests (Ulrich et al. 2004).

However, in southern and central Sweden, small-scale poplar plantations can increase floristic diversity in landscapes dominated by agriculture (Weih et al. 2003). Although when compared to old-growth mixed deciduous forests in different regions of Sweden, species richness of poplar plantations was similar or lower (Weih et al. 2003).

An Estonian study on epiphytic lichens and bryophytes found that short-rotation hybrid aspen plantation located close to colonization sources, can provide temporary habitats for forest species and thus partly contribute to preserving landscape-scale biodiversity. This means that remaining green-tree retention trees after harvest in these plantations will probably have a positive effect on biodiversity value of those short-term communities as suggested be (Randlane et al. 2017).

Environmental aspects of fast growing tree species

The majority of Swedish forests consists of managed monocultural stands of *P. abies* and *P. sylvestris* (SFA 2014). In southern Sweden *P. abies* is the more predominating tree species of the two, and is often considered when regenerating in fertile sites, such as on previous arable land. Since *P. abies* stands in fertile sites often become dense and dark, they are usually fairly poor from a biodiversity point of view (Hedwall et al. 2010).

There are reasons to believe that fast growing tree species may be beneficial for biodiversity. Their fast growth may result in higher amounts of dead wood which creates habitats for a wide range of organisms (Seibold et al. 2015). They are also able to fast-accomplishing big sizes and bark structure characteristic for much older broadleaves. The complexity of bark structures in the forest may determine abundance of microhabitats for a variety of organisms and ecosystem functions (Michel and Winter 2009). As a pioneer species, *P. trichocarpa* and *L.×eurolepis* are light-demanding and forming crowns which allow much light on the forest floor. With more light available to the other layers of the stand, there is a greater probability for other life forms to benefit. Moreover, the additional share of broadleaves in Sweden would implement some variation in the landscape so heavily dominated by coniferous trees.

However, there is still a big knowledge gap about the environmental impact of non-native tree species plantations in Northern Europe on the native flora and fauna.

In this study, I examine epiphytic lichens to estimate biodiversity in two non-native and two native tree species stands.

Lichens.

Lichens may play a role in the nutrient cycle and water storage in the forest (Galloway 1992). The mass of nutrients stored in lichen biomass in the forest can be as high as 27 kg/ha of N, 3,6 kg/ha of P, and 9 kg/ha of K (Pike 1978). We know relatively little about lichens importance in forest ecosystem in compare to other forest taxa (Pike, 1978).

Although there is research on the value of lichens as a biodiversity estimate (Bäcklund et al., 2016), most reviewed scientific papers are focusing on using lichens as indicators of pollution (Thormann 2006). Lichens are graceful object to be monitored. However, they grow slowly and steadily, and do not represent dynamic of birds or even vascular plants. It is worth to add that the investigation of lichens is not depending on season of the year (except for change of appearance for some of them while being damp or very dry). They are perseverant organisms and their resilience was already tested in Martian-like condition (de Vera et al. 2010).

Lichens grows in a wide range of shapes and forms, and how do they look depends mostly on their fungal component. In Sweden approximately 2000 lichen species are found from which 800 species are mainly found in forests (Rudolphi, 2007). This wide variety of organisms from which many have different living requirements makes them an excellent tool in assessing environmental quality.

The lichens examined in this study are all epiphytes. This means that they are closely dependent on a woody plant host for their growth and spread. Previous studies have shown that light, moisture condition in the stand and tree species seem to have the closest connection with epiphytic lichen species (Bäcklund et al. 2016). The study of lichen flora of *P. abies* in Norway shows correlation between tree size and lichen species richness, however stand age, altitude and vegetation type were found to be the most important for explaining the patterns of species distributions (Holien 1997). Different lichen species and lichen communities require different suitable habitat. This is why the use of lichens would potentially result in reliable data about micro-habitat diversity in different stands. Each of these tree species can potentially provide unique set of habitats that may attract different lichen species.

Aim of the study

There is an increasing use of non-native tree species as an alternative for conventional timber and biomass production. Simultaneously, the knowledge gap in the environmental impact of fast growing tree species still remains more and more important (Lindbladh et al. 2014). As a contribution to fill this knowledge gap, I compared lichen communities of a tree species experiment in southern Sweden. I inventoried four stands: two of native tree species (*P. abies* and *B. pendula*), and two of non-native trees species (*P. trichocarpa* and *L.×eurolepis*). The subject of the inventory were epiphytic lichens growing on boles of the trees from ground level up to 2 meters height.

Research questions:

- What is the effect of tree species on lichen diversity and composition?
- Does occurrence of lichens on trees boles depend on micro-climate (cardinal direction of the bole) or on a diameter at breast height of the tree?

2. Materials & methods

2.1. Bullstofta

The experimental site is located in Bullstofta, approximately 20 kilometres south-east of Helsingborg (Fig. 1) in the southernmost part of Sweden. The experiment is located on former agricultural land. The surrounding area consists of a mosaic of arable land and small, fragmented forests. Within the closest 5 km radius from the Bullstofta experiment, arable land is the predominating land use. The forests within this circle mostly consist of fragmented plantations, nevertheless, there are a few patches of noble deciduous old-growth in the closest surroundings.

Figure 1. Bullstofta located in Skåne, southern Sweden.

2.2. Description of the experimental setup

This study was carried out in a previously established tree species experiment were non-native tree species (like Douglas fir *Pseudotsuga menziesii*, Sitka spruce *Picea sitchensis*, Balsam fir *Abies balsamea*, Hybrid larch *Larix×eurolepis*, Hybrid aspen *Populus tremula x tremuloides*, Balsam poplar *Populus trichocarpa*) and most the common native tree species (Norway spruce *Picea abies*, Scots pine *Pinus sylvestris*, and Silver birch *Betula pendula*) were planted in a replicated block design with three replicates (Fig. 2). This setup enables us to increase the knowledge of both production and ecological aspects of the chosen tree species under comparable site conditions.

The trial site is a part of the Farming Society's experimental farm, which was previously used for cultivation. The ground is completely flat and homogeneous.

The trial in Bullstofta has been constructed with eight different tree species, each represented by one or more different provenances/clones.

Sites were established on a former arable land. In early autumn 1992, the ground was treated with Roundup, then in the following spring, the ground has been harrowed. In May 1993 planting began in parcels of 36 x 36 meters and a spacing of 2 x 2 meters. Sites were fenced with 2 meters high fence to prevent game damage. Within a parcel, the different provenances/clones were planted. The experimental plants were grown at SkogForsk stations in Brunsberg and Ekebo and Svenska Skogsplantor's nursery in Kolleberga. All plants were labelled to enable individual mapping. The experiment occupies 3,1 hectare with 7776 plant positions.

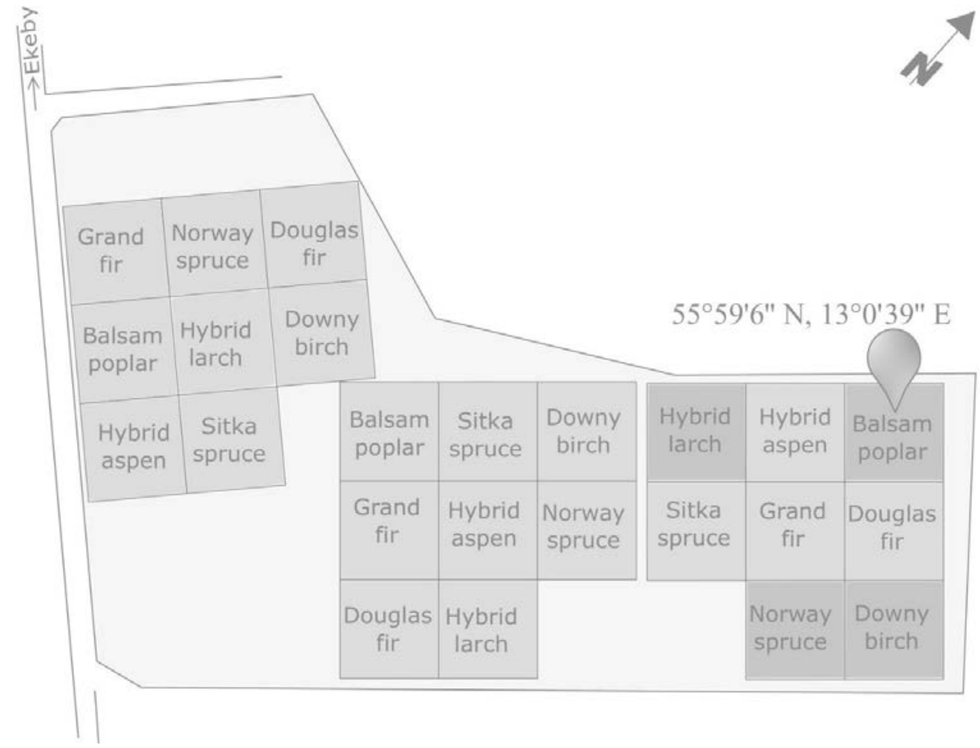

Figure 2. Map of Bullstofta experimental site. The dark grey stands are the ones examined in this study.

2.3. Stand description

In this inventory I selected to study; *P. trichocarpa*, *L.×eurolepis*, *B. pendula* and *P. abies* stands (see dark grey plots on Fig. 2). All stands were thinned. There was a noticeable amount of deadwood in each stand; mostly small dimension wood, small branches, thinning leftovers. All of the stands are very bright, except the spruce stand. All stands were 27 years old. All stand are monocultures with only one main species planted initially. However, stands of *P. trichocarpa*, *L.×eurolepis*, and *B. pendula* were quite diverse. In the *B. pendula* stand species like Black elder *Sambucus nigra*, Hawthorn *Crataegus spp.*, Beech *Fagus sylvatica*, and Oak *Quercus spp.* were noticed (Fig. 3). In the *L.×eurolepis* stand the understory was even thicker, with more species noticed (Black elder *Sambucus nigra*, Common hazel *Corylus avellana*, European ash *Fraxinus excelsior*, Hawthorn *Crataegus spp.*, Rowan *Sorbus aucuparia*, Alder *Alnus spp.* etc.) and a dense layer of *Rubus spp*. (Fig. 4). The *P. trichocarpa* stand also showed well-developed understory, mainly: Hawthorn *Crataegus spp.*, European hornbeam *Carpinus betulus,* European ash *Fraxinus excelsior*, European beech *Fagus sylvatica,* and Wild cherry *Prunus avium* (Fig. 6). In the *P. abies* stand no other woody species were found and the stand looked quite homogeneous (Fig. 5).

Figure 3. Birch stand, Bullstofta.

Figure 4. Larch stand, Bullstofta.

Figure 5. Spruce stand, Bullstofta.

Figure 6. Poplar stand, Bullstofta. Tree with number 1617 (in the red circle) is the one where I found first Alyxoria ochrocheila.

2.4. Design of the inventory.

20 sample trees were selected in each of the four stands (birch, larch, poplar and spruce). To designate the trees, the stands were divided into 20 smaller sites by creating a grid followed by marking these with ribbon on the edges of the stand. Before that, the size of the stands were reduce from 36 x 36 meters to 30 by 30 meters, due to edge effect limitation. After that, those trees were chosen for sampling that were the closest to the middle of each site (Fig. 7).

On each of the selected trees, the trunks were carefully examined from the bottom of the trunk up to 2 m high. All occurring lichens were considered. If known, the lichens were noted down. If not – the samples were taken to further examination in the laboratory. All findings were differentiated to the northern and the southern side of bole. There was no quantitative examination, only occurrence. The diameter in breast height (DBH) of each selected tree was recorded with a calliper.

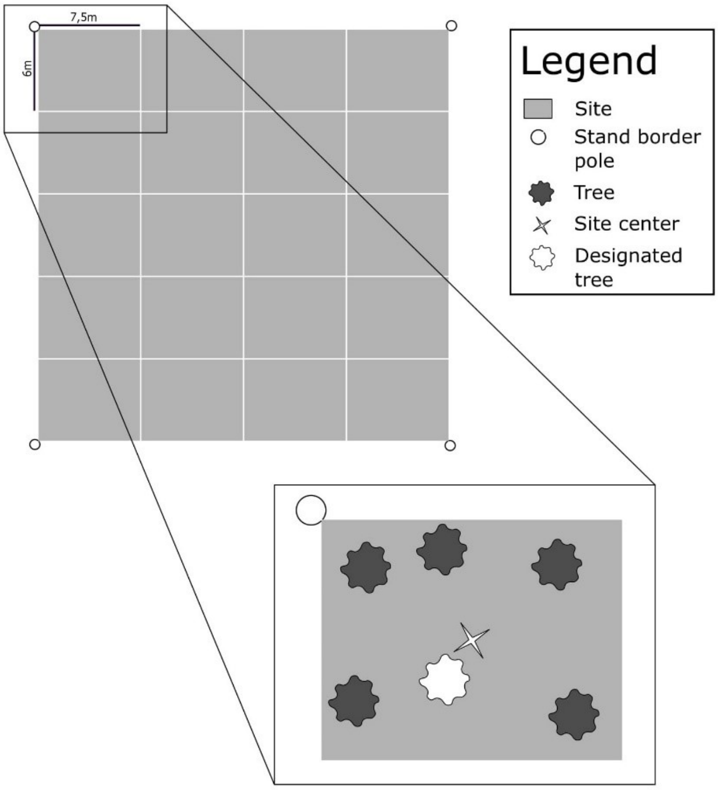

Figure 7. Stand divided into 20 sites, 6m x 7,5m each. On each of those I located one tree which was the closest to the middle of the site.

Each tree was examined with a loupe; Opticron 10x21 mm with LED and UV light. Samples were broken down or cut with the piece of the bark and secured in a labelled paper envelope. In the lab, samples were checked closer under the microscope and tested with potassium or chlorine solution (if necessary) inorder to identify the species. Die Flechten Deutschlands (Wirth et al. 2013), Svenska skorplavar och svampar som växer på dem (Foucard 2001) and internet guides were used as identification literature. Part of the samples I discussed with Lisa Petersson (Southern Swedish Forest Research Centre). Identification of some *Lecanora spp.*, based on collected samples, was supported by Ulf Arup, head of the Biological museum at Lund University. The occurrence of *Alyxoria ochrocheila* and identification of some *Lecanora spp.* were confirmed by Göran Thor, Professor at Department of Ecology, Unit for Conservation Biology, SLU Uppsala. The confirmation was based on a delivered much-magnified picture in high resolution.

2.5. Data analysis

Data was analysed in R version 3.5.1 (2018-07-02), with packages vegan 2.5-6 and ggplot2. To produce maps and graphics I used QGIS version 3.8.1-Zanzibar and Inkscape 0.92.4.

In order to examine the variation in lichen communities, I used non-metric multidimensional scaling (NMDS) by running metaMDS function from vegan package (Oksanen et al., 2019). I included information about side of the trunk where the lichens occurred. In this thesis one community of lichens means all lichens that I found on one (northern or southern) side of one tree.

To estimate species richness and test possible correlation I used nonparametric statistics tests functions richness in RStudio. I used Spearman’s rank correlation, Kruskal-Wallis rank sum and Pearson’s product-moment correlation.

3. Results

3.1. Lichen species

In all four stands together I found at least 22 different lichen species (Table 1). There were two species that I was able to identify only to genus level (*Lepraria spp.* and *Cladonia spp*). Some of the *Lecanora* lichens were determined to species level (*L. chlarotera, L. argentata, L. pulicaris*). These of *Lecanora* that I have been able to identify only to genus occur in the table as *Lecanora spp.*

The majority of lichens found were crustose species (12 of them). There were 7 species of foliose and 3 species of fruticose lichens. The most common crustose lichen was *Lepraria spp.* (recorded on 65 trees) followed by *Coenogonium pinieti* (23 trees). The most common foliose lichen was *Hypogymnia physodes*. The most common fruticose lichens were *Cladonia spp.* (21 trees) and *Evernia prunastri* (20 trees). Most of the recorded species are lichens commonly observed in Sweden (Table 1). Twelve of them were described as very common in Sweden or Southern Sweden. There were two species less likely to occur in Sweden: *Candelariella superdistans* described as less common and *Alyxoria ochrocheila* – a very rare species (Fig. 8), which current Swedish Red list status is near threatened (NT).

All species found in this study are forest associated. The majority of the species is related with deciduous forests (both noble and trivial broadleaves). I found six lichen species for which the described habitat is noble deciduous forest (*A. ochrocheila, A. mediella, C. pineti, G. scripta, L. chlarotera, P. adscendens*). All of these six species occured in poplar stands. Only one of these species was found in all others stands (*C. pineti)*.

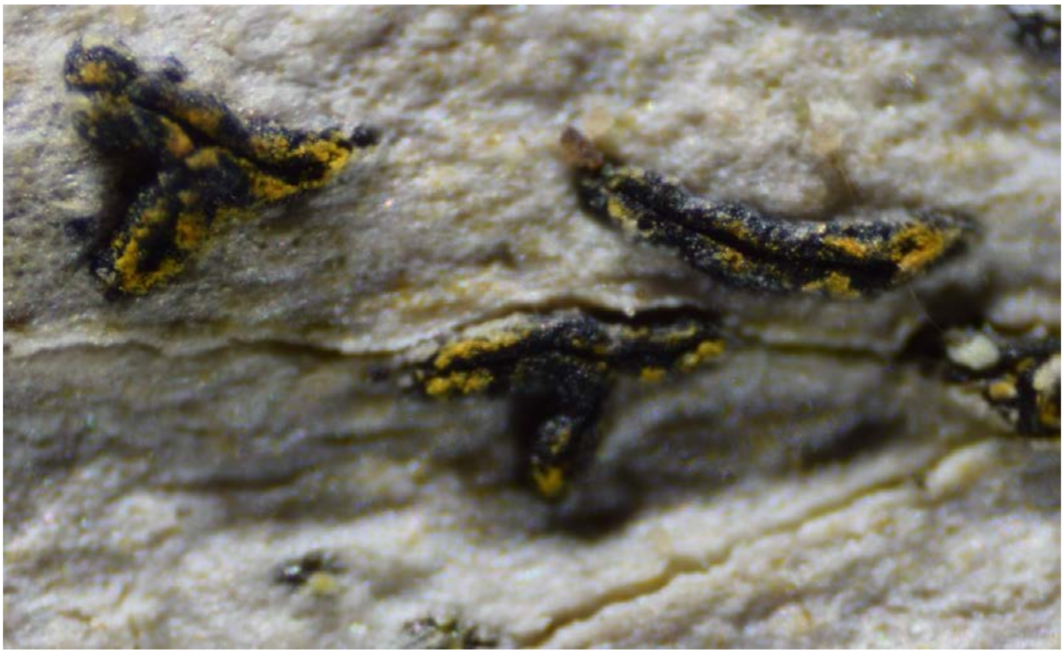

Figure 8. Alyxoria ochrocheila with characteristic yellow powder on the apothecia.

3.2. Spruce stand

There were six species of lichens found in the spruce stand. These were: *Cladonia spp., C. pineti, E. prunastri, Lepraria spp., Melanelixia glabratula* and *P. argena.* Most of these species are very common (Hallingbäck 1995). Most of the specimens found on trees in the spruce stand were very small and poorly developed. In many cases there was barely enough material to identify the species. Just two of mentioned species were found on many trees (these were *C. pineti* and *Lepraria spp.).* The other four species found in this stand were recorded on three or less than three different trees. Considering microhabitats available for lichens the stand itself was very homogenous. All trees grew in even spatial distribution, reaching similar DBH. There was no structural variation like gaps or others.

Table 1. Lichens found in the studied stands, with description of their growth form, habitat and number of colonized trees. Scale: 5- very common, 4- common, 3- less common, 2- rare, 1- very rare. Based on Hallingbäck, Tomas. Ekologisk katalog över lavar. Artdatabanken 1995.

Lichen species	Occurrence (1- rare, 5- common)	Form	Habitat	Nr of colonized trees
Alyxoria_ochrocheila	1	crustose	Mixed noble deciduous forest and foliage. Preferably near the coast.	2
Arthonia_mediella	4	crustose	Noble deciduous forest and fir forest.	5
Candelariella_superdistans	3	crustose	Spruce forest with aspen type and various human-affected environments.	3
Cladonia_sp.	-	fruticose	-	21
Coenogonium_pineti	4	crustose	Wetland forest, noble deciduous forest and mixed forest.	26
Evernia_prunastri	5	fruticose	Deciduous forest, arable islands, bushland, alley etc.	20
Graphis_scripta	5	crustose	Mixed noble deciduous forest and mixed forest.	2
Hypogymnia_physodes	5	foliose	Forests, slopes and various human-influenced environments.	30
Lecanora_chlarotera	5	crustose	Trivial deciduous forest and coniferous forest with deciduous leaves. Even noble deciduous forest.	2
Lecanora_populicola	4	crustose	Spruce forest and aspen forest.	10
Lecanora_pulicaris	5	crustose	Trivial deciduous forest, pine forest and spruce forest.	20
Lecanora_sp.	-	crustose	-	7
Lecidella_euphorea	4	crustose	Trivial deciduous forest, spruce forest with aspen type.	13
Lepraria_sp.	-	crustose	-	65
Melanelixia_glabratula	5	foliose	Trivial deciduous forest, mountain slopes and various environments.	14
Parmeliopsis_ambigua	5	foliose	Forest and pastures.	3
Phaeophyscia_ciliata	4	foliose	Aspen forest, alley, park, garden and farm.	14
Phlyctis_argena	5	crustose	Mixed forest with deciduous forest, oak and hazelnut grove.	14

Physcia_adscendens	5	foliose	Noble deciduous forests, aspen forests, trees and woodland.	3
Physcia_tenella	5	foliose	Aspen forest, alley, park, garden and farm.	7
Ramalina_fraxinea	5	fruticose	Alley, park, garden or farm.	1
Vulpicida_pinastri	5	foliose	Spruce and mixed forest.	5

3.3. Birch stand

In the birch stand I found seven lichen species. These were: *Cladonia spp.*, *C. pineti*, *E. prunastri*, *H. physodes*, *L. pulicaris*, *Lepraria spp.* and *M. glabratula.* I found here five of six species recorded in the spruce stand (all of them but *P. argena*). The specimens were not very abundant but still I found much more specimens than in spruce stand. Most of the lichens were more developed and therefore easier to identify. Three lichen species were found on most of the examined trees in this stand. These were: *Lepraria spp.* (on 19 trees), *L. pulicaris* (on 18 trees) and *H. physodes* (on 11 trees).

3.4. Larch stand

In the larch stand I found nine species of lichens. These were: *Cladonia spp.*, *C. pineti*, *E. prunastri*, *H. physodes*, *Lecanora spp.*, *Lepraria spp.*, *M. glabratula*, *P. ambigua* and *V. pinastri.* All species found in the larch stand are common or very common in Southern Sweden. I found many specimens of *Cladonia* genus; most likely specimens of more than one species. The most common species in this stand were *Lepraria spp.* and *H. physodes.* Many of the specimens found here were abundant and well developed. Different lichen species grew close together or even overlapped with other lichen species and with mosses; *Cladonia spp.* in particular.

3.5. Poplar stand

In the poplar stand I found 18 species which were: *A. ochrocheila, A. mediella, C. superdistans, Cladonia spp., E. prunastri, G. scripta, L. chlarotera, L. argentata, L. pulicaris, Lecanora spp., L. euphorea, Lepraria spp., M. glabratula, P. ciliate, P. argena, P. adscendens, P. tenella* and *V. pinastri.* Ten out of eighteen species were found only in the poplar stand, not in any other stand that I examined. Two of these ten species are not common for this part of Sweden (*C. superdistans* is considered less common and *A. ochrocheila* is considered very rare (Hallingbäck 1995)). Most of the lichens in the poplar stand were well developed.

3.6. Lichen species richness

The highest species richness was found in the poplar and larch stands (Fig. 9). The lowest species richness was recorded in the spruce stand. The species richness was slightly higher on northern sides of the boles in birch, larch and poplar stands. There was one tree in spruce stand on which I did not find any lichens. This tree is not shown in figure 9.

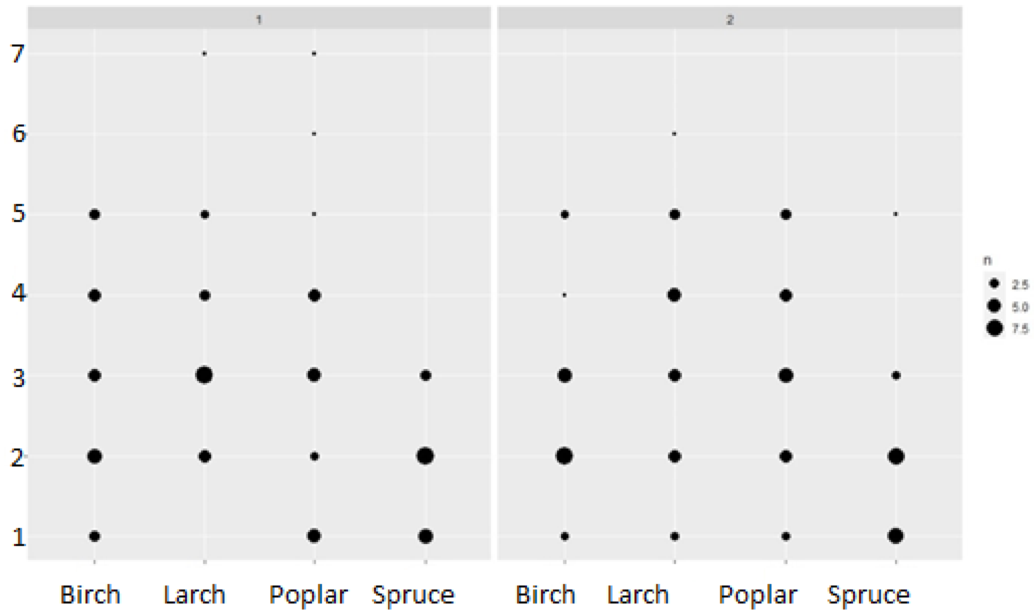

Figure 9. Species richness. The Y-axis shows the number of lichens species recorded on one tree. n is a number of trees on which certain amount of lichens species was recorded. The X-axis shows

stands of chosen tree species. The left part of the figure (1) reflects northern side of trunks. The right part of the figure (2) reflects southern side of the trunks.

In result of paired comparisons between trees species, the lichen species richness in spruce stand is significantly different from the rest of the stands (Tab.2). Moreover, the Dunn test shows that spruce is different from the other threes, and that birch and larch are almost significantly different from each other (Tab.3).

Table 2. Mean lichen species richness per plot.

	Mean richness	Richness SD	Significance letter
Birch	2,75	1,21	a
Larch	3,34	1,32	a
Poplar	3,08	1,5	a
Spruce	1,86	0,867	b

Note (Tab.2); different letters indicate significant differences *p=0.05*.

Table 3. Dunn's test comparison of lichen species richness by tree species (p-values).

	Birch	Larch	Poplar
Larch	0,05500		
Poplar	0,34320	0,33760	
Spruce	0,00150	< 0,001	< 0,001

The lichens species richness per plot (one plot is one side of one tree) is pictured below with consideration of size of the tree (DBH) and north and south plots distinction (Fig. 10). The mean amount of lichens species (Tab.2) was between 1,86 (*P. abies*) and 3,34 (*P. trichocarpa* and *L. eurolepis*). The records varied the most in *P. trichocarpa* and *L. eurolepis* stands where on one plot from 1 to 7 species were recorded.

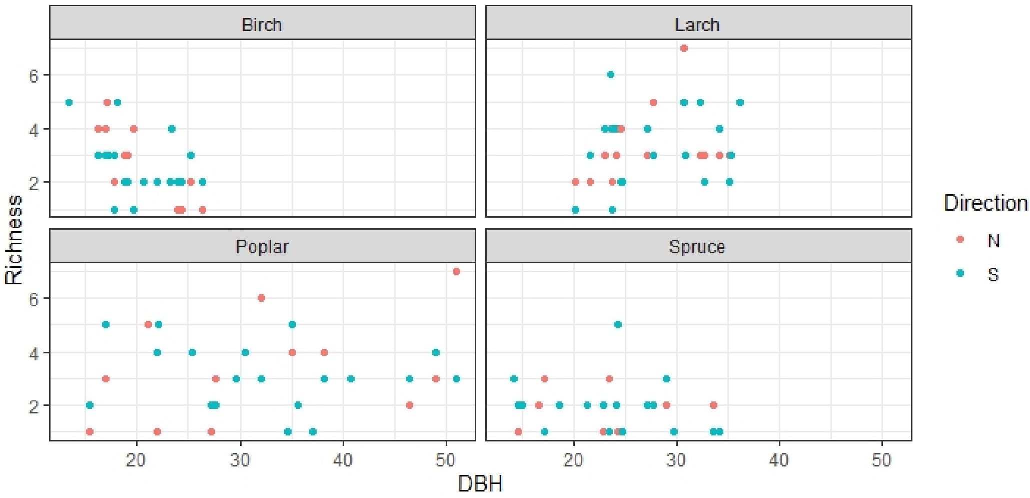

Figure 10. Lichens species richness and DBH distribution with north and south distinction.

3.7. Lichen communities

Non-metric multidimensional scaling (NMDS) was carried out to describe lichen communities in all four examined stands. The stress value for this scaling was 0,093 (where preferable score should be below 0,2). This method shows how diverse (or not) lichen communities are. One lichen community was the total of lichen species found on one side (northern or southern) of one tree. One lichen community is pictured as one symbol (Fig. 11). The closer the symbols are to each other, the more similar communities are represented by this symbols.

Lichens communities on poplar showed the greatest diversification. Lichen communities of larch and birch stands are the most similar and overlap with less than 50%. Note that the symbols for larch and spruce have a some degree of overlap. Moreover, many of the spruce plots fully overlap with each other so it seems like there are much less green points on the diagram (Fig. 11).

Mean lichen species richness pre plot (plot = one side of a tree) in all trees was 2,77 lichen species per plot (Tab. 2). It was the highest in larch stand; 3,34 lichen species per plot, followed by poplar stand (3,08). Tree species prove to be statistically significant for lichens richness. In Kruskal-Wallis rank sum test of lichen species richness by tree species, p-value was 3,583e-06. The correlation between tree species and richness of lichen species is significant.

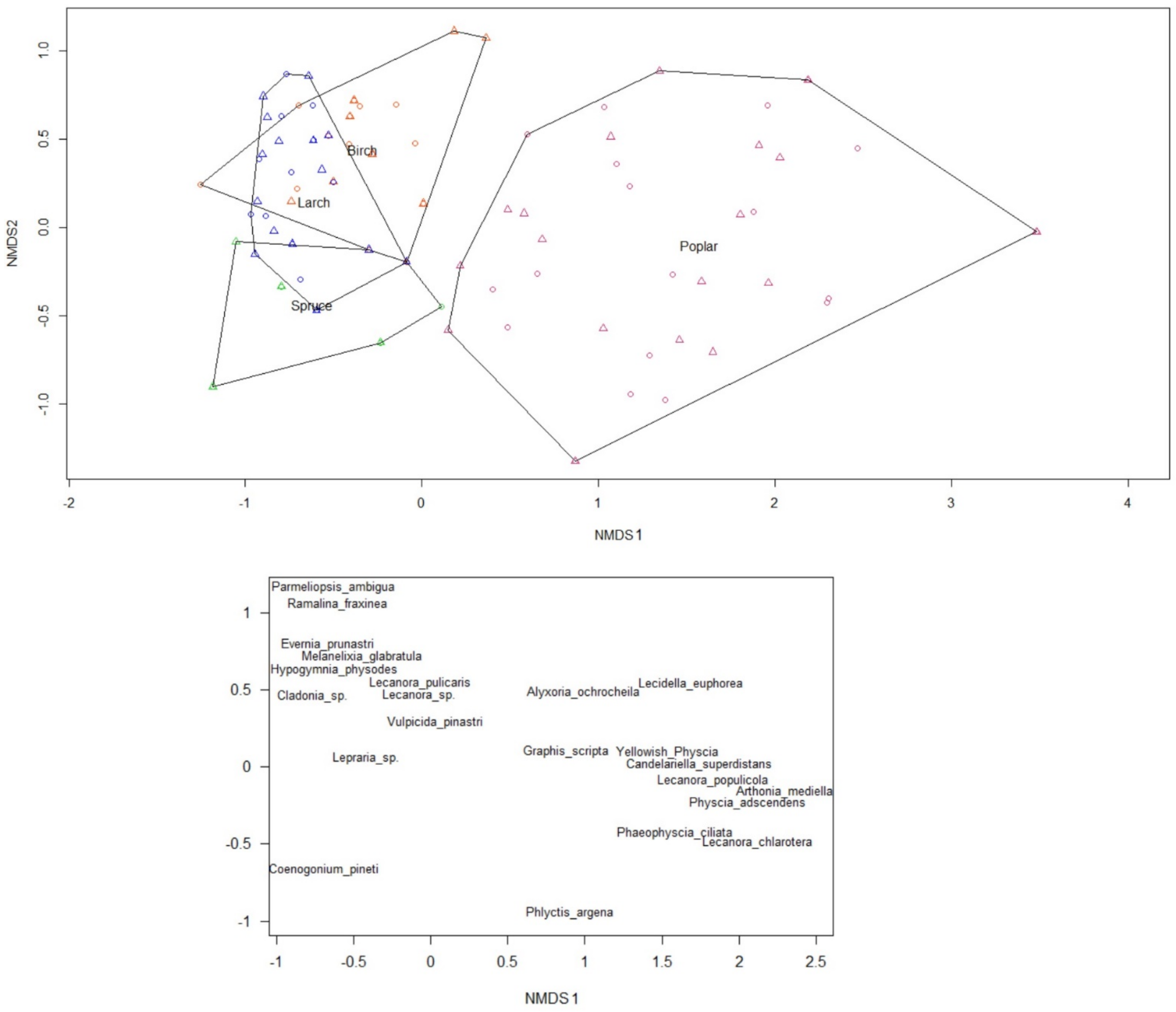

Figure 11. Ordination diagram of non-metric multidimensional scaling (NMDS) showing lichen communities. The upper picture: blue – larch, orange – birch, green – spruce, pink – poplar. Triangles – north, circles – south. The lower picture: lichens species.

3.8. Northern vs. southern side of the bole

Northern and southern side of each tree were examined separately (Fig. 10). Some lichen species were slightly more common on one side of the trunk. However, these differences varied a lot in between lichen species and tree species and no clear pattern can be identified. As a result of this, statistical analysis showed that there was no significance between northern and southern side of the trunk (Wilcoxon signed-rank test p-value 0,8453, and a Kruskal–Wallis test by ranks p-value 0,928).

3.9. DBH

The diameter at breast high of the tree does not seem to have great impact on lichen species richness on that tree (Fig. 12 - 15). In three of four stands the tree with the largest amount of lichen species was not the tree of the largest DBH. In the larch stand, the thickest tree had the largest number of lichen species on it (7 species). But there were two more trees with the same number of species. Stands also varied in terms of DBH distribution. The most evenly distributed DBH was found in the *B. pendula* stand (range 13,4 to 26,3 cm). The most diverse tree dimensions within the stand were observed in the *P. trichocarpa* stand (range 15,3 cm to 58 cm). The Spearman's tests showed that DBH was not statistically significant for lichen species richness (p=0,5762). Neither was DBH tested for each stand separately in the Kruskal-Wallis test. The Pearson's test showed similar results except for the birch stand. The birch stand in Pearson's test was the only one where the DHB of tree was statistically significant for lichen richness (Tab.4), however it was not statistically significant in the Kruskal-Wallis test.

Table 4. Mean DBH and results of Spearman's, Pearson's and Kruskal-Wallis of lichen species richness by DBH.

	mean DBH	Spearman's rank correlation p-value	Pearson's product-moment correlation p-value	Kruskal-Wallis rank sum test p-value
All plots	25,96	0,5762	0,2055	
Spruce	23,64		0,0897	0,8364
Birch	19,95		**0,0003**	0,4823
Larch	28,02		0,1152	0,928
Poplar	32,42		0,618	0,7425

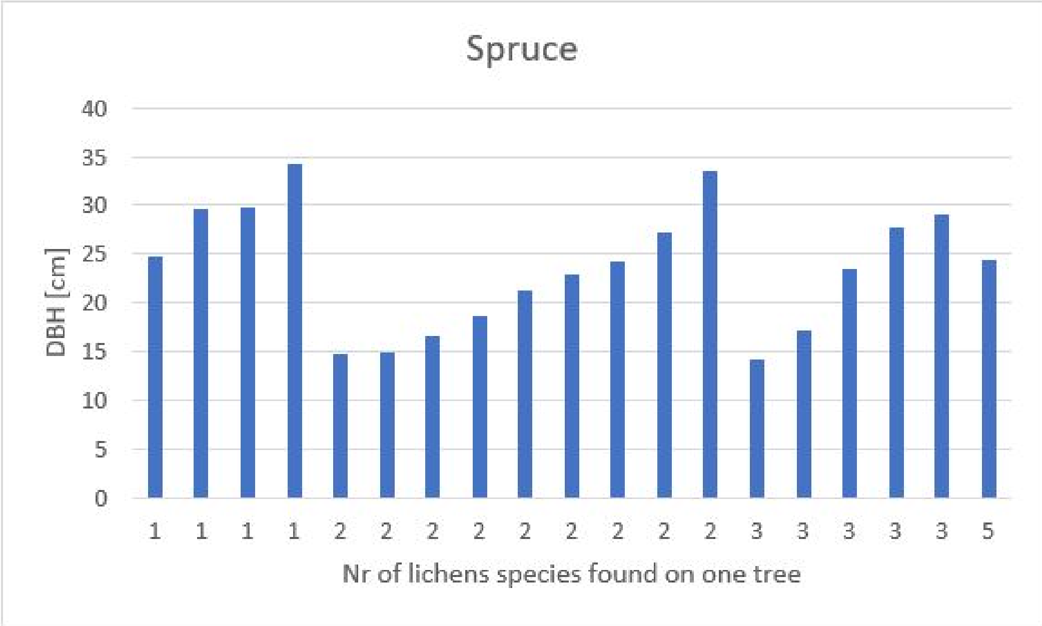

Figure 12. Number of lichen species recorded in relation to spruce DBH. One bar = one tree.

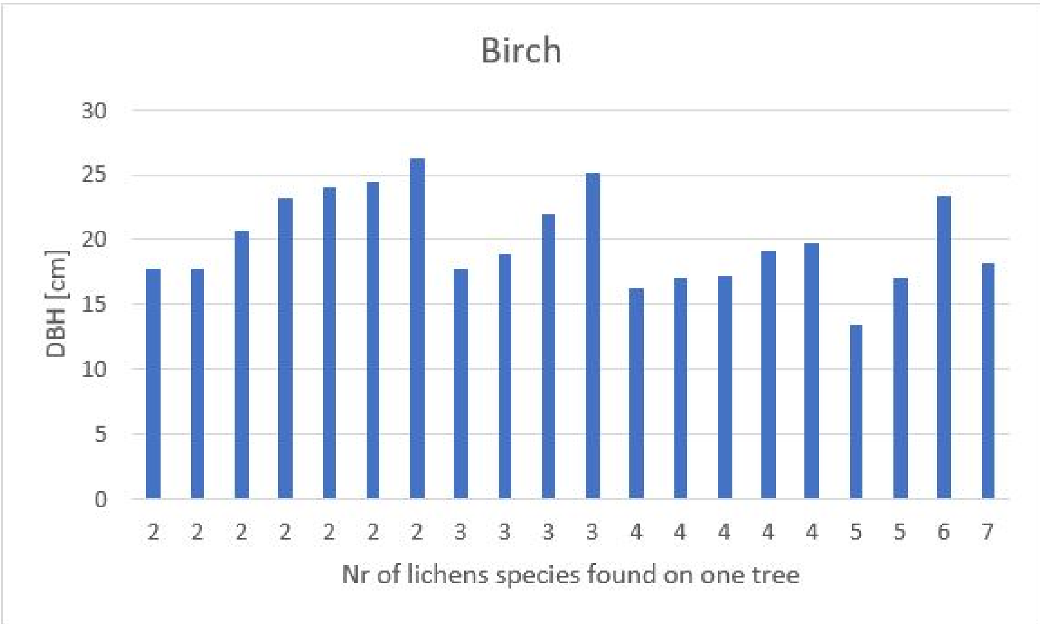

Figure 13. Birch DBH. One bar = one tree.

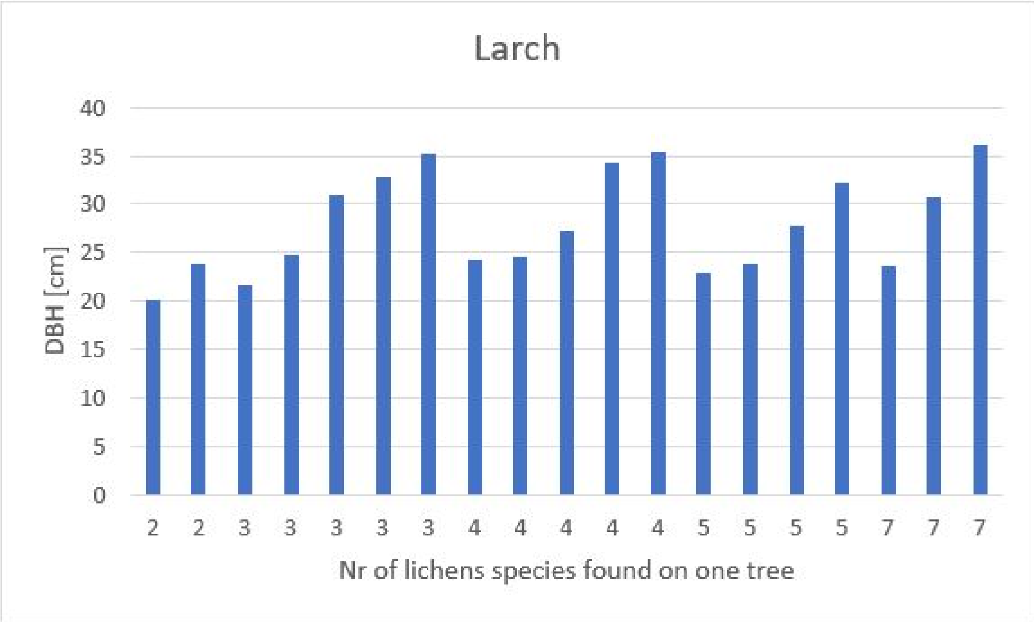

Figure 14. Larch DBH. One bar = one tree.

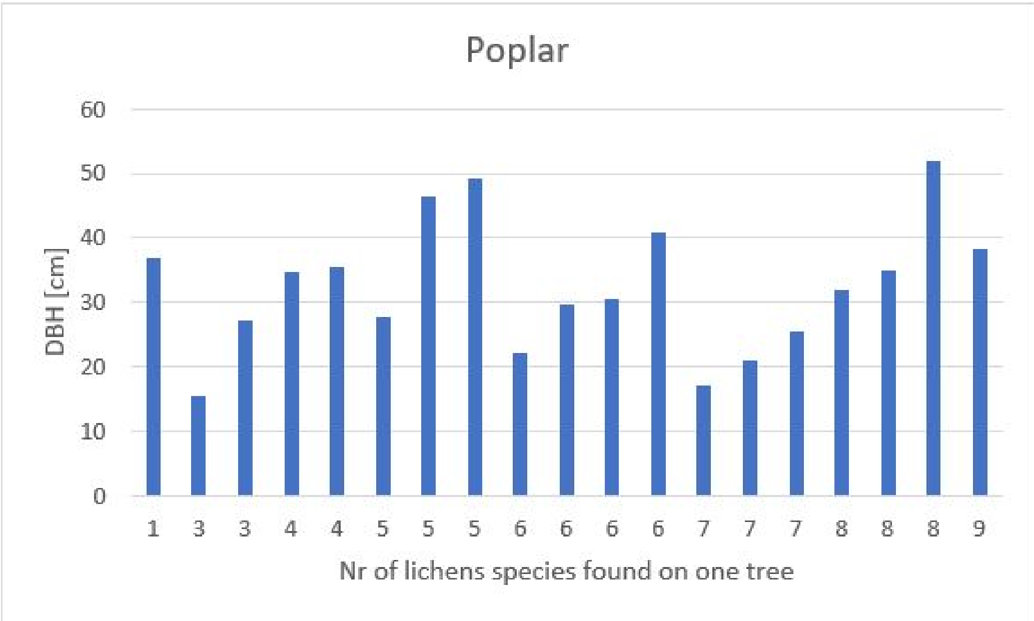

Figure 15. Poplar DBH. One bar = one tree.

4. Discussion

In this study, I examined species richness and community composition of epiphytic lichens in four tree stands. All four stands are monocultures, with only one main tree species planted initially. They all were the same age which is 27 years. These were stands of tree species native in Sweden (stands of *P. abies* and *B. pendula*) and non-native in Sweden (stands of *P. trichocarpa* and *L.×eurolepis*). I investigated this subject to increase the knowledge on biodiversity patterns in these non-native tree species that could be cultivated in Sweden because of their production and economic advantages.

4.1. Main findings

This study shows that the examined non-native species stands are richer in lichen species than the two stand of native tree species. The richest in species was the *P. trichocarpa* stand (with eighteen lichen species), followed by *L.×eurolepis* stand (nine species). The lowest lichen richness was recorded in the *P. abies* stand. The lichens communities were the most diverse in the *P. trichocarpa* stand.

4.2. Lichen diversity in the stands

In this study, the stand of Norway spruce *Picea abies* showed the lowest lichen richness and the lowest lichen community diversity. The other native species stand, Silver birch *Betula pendula,* was more diverse but only one lichen species richer. In comparison, both examined non-native species (Balsam poplar *Populus trichocarpa* and Hybrid larch *Larix×eurolepis)* stands were much more diverse, and therefore offering more habitats for different lichens species.

Commercial plantations of *P. abies* are generally considered to be forests of a low conservation values for flora and fauna. The species richness of lichens in production stands of *P. abies* may even decrease while stand get older (Bäcklund et al. 2016). However, *P. abies* is the species with the highest amount of other species (both red-listed and least-concern species) related in terms of constituting food or habitat for this species (SLU 2020).

The low species richness in the *P. abies* stand is most likely the effect of:

1) Light limitations due to dense canopy. The algae component in lichen needs sufficient light to perform photosynthesis. With limited light lichens cannot thrive or even occur.
2) Even spacing and even tree size, which lead to homogeneous light and moisture conditions on individual trees.
3) Smooth and homogeneous bark.

Usually, another reason for lack of lichens might be the high competition from the bryophytes. Although that was not the case in this study; I did not find many bryophytes that might be a threat to lichens in the examined *P. abies* stand. The bryophyte richness and therefore their impact on lichens communities can be influenced by edge effects. In a Canadian study the habitat heterogeneity and the distance from the edge of the stand were pointed out as the most important variables affecting bryophyte and lichen species richness (Gignac and Dale 2005).

The study showed higher lichens diversity in the stands of *P. trichocarpa* and *L.×eurolepis* than in stands of *P. abies* and *B. pendula.* Both of investigated non-native species are fast growing species with quite complex bark structure and heterogeneous stand architecture. Trees in these stands were less evenly distributed than in the *P. abies* stand. In both *P. trichocarpa* and *L.×eurolepis* stands, I found a complex understory with many other tree species.

4.3. Can poplars help improve biodiversity?

The stand of *P. trichocarpa* presented the greatest lichen diversity and the most complex lichens communities. As a fast growing tree species, *P. trichocarpa* can reach relatively large size in a short time. That trait allows develop a trunk size and a bark structure characteristic for much older trees. As shown in a study on microhabitat of old oaks (Ranius et al. 2008), the number of lichens increases on older trees (over 100 years old oaks) and when bark crevice depth increased. There are more microhabitats in old standing living trees than in younger monocultures (Paillet et al. 2017). As a fast growing species, *P. trichocarpa* is aging fast. It means also that *P. trichocarpa* can produce a considerable amount of dead wood (dead branches and dead trees), and create microhabitats for other species, like insects or birds.

The biodiversity function of old trees like oaks can potentially be supported by *Populus spp.* and probably by other fast growing tree species. As found in the paper about intensive short rotation forestry in boreal climates (Weih 2004), species like poplars and willows might help increasing biodiversity in boreal forests as well as in open agricultural landscape. Considering the short rotation of most *Populus spp.* based stand, the biodiversity support would require leaving retention trees at the end of rotation. In another Canadian study about forest development, structure, and diversity, two old-growth forests types were compared; the white spruce forests and balsam poplar forests. While both types of forests may persist the same time period (in excess of 300 years), the poplars are aging much faster. Therefore, the poplar stand can perform ecological functions of old-growth forest much earlier. In White spruces stands, old-growth forest attributes begin to appear after the stand reached the age of 160 years. Similar condition were accomplished by poplar stands in half of that time (when stands turned 80 years) (Timoney and Robinson 1996).

It is worth to mention that examined stands were surounded by a mosaic of agricultural land and some patches or groups of old noble deciduoud trees. The local proximity of woodlands can result in a larger species-pool for colonization into aspen stands nested within this woodland matrix.

4.4. The side of the bole and the diameter at breast height

This study did not show a clear correlation between lichen species richness and DBH of the tree, or the side on which lichens are occurring. Based on literature, the size of the tree seems to matter the more, the older it is (Ranius et al. 2008). On the other hand, as indicated in (Lie et al. 2009): the tree size and tree age are mostly positively correlated, which might blur the interpretation of the separate effects of tree size and tree age. A few centimeter difference in DBH in a relatively young age does not look like a significant factor.

The expected difference in lichen communities on northern and southern sides of the bole were not confirmed either. In my study the side of the tree was not significantly relevant for lichens occurrence. One possible reason for this is the inventory in this theses have a limitation of available data.

In other studies the northern side of the trunk, especially while coupled with stem leaning, is observed to create better conditions for bryophytes (Ranius et al. 2008). Therefore, lichens can experience tougher competition from bryophytes and less lichens may occur. The north facing side may also provide less suitable condition for light demanding lichens.

5. Conclusion

1) Investigated non-native tree species seem to have potential to increase biodiversity in production stands.
2) Considering the bark complexity, fast growth and stand architecture, species like poplar may support ecological functions similar to those provided by great-dimension, old trees like oaks
3) Addressing both production and nature conversation potential, it is recommended to continue the study. Especially comparing with similar experiments in other parts of Sweden and do lichen inventories using quantitative methods.

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Appendix 1

Table 5. Lichens on northern and southern side of boles.

	BIRCH		LARCH		POPLAR		SPRUCE	
	N	S	N	S	N	S	N	S
Alyxoria_ochrocheila	0	0	0	0	2	0	0	0
Arthonia_mediella	0	0	0	0	5	4	0	0
Candelariella_superdistans	0	0	0	0	3	1	0	0
Cladonia_sp.	4	1	7	8	1	0	1	3
Coenogonium_pineti	2	1	8	7	0	0	13	12
Evernia_prunastri	6	2	7	8	1	1	0	1
Graphis_scripta	0	0	0	0	2	0	0	0
Hypogymnia_physodes	9	10	16	12	0	0	0	0
Lecanora_chlarotera	0	0	0	0	2	1	0	0
Lecanora_populicola	0	0	0	0	5	9	0	0
Lecanora_pulicaris	13	18	0	0	1	1	0	0
Lecanora_sp.	0	0	0	4	2	2	0	0
Lecidella_euphorea	0	0	0	0	7	11	0	0
Lepraria_sp.	19	18	19	19	8	1	16	16
Melanelixia_glabratula	4	2	4	1	1	1	0	1
Parmeliopsis_ambigua	0	0	1	3	0	0	0	0
Phaeophyscia_ciliata	0	0	0	0	7	11	0	0
Phlyctis_argena	0	0	0	0	7	7	3	1
Physcia_adscendens	0	0	0	0	1	2	0	0
Physcia_tenella	0	0	0	0	2	6	0	0
Ramalina_fraxinea	1	0	0	0	0	0	0	0
Vulpicida_pinastri	0	0	2	1	1	1	0	0
	58	52	64	63	58	59	33	34