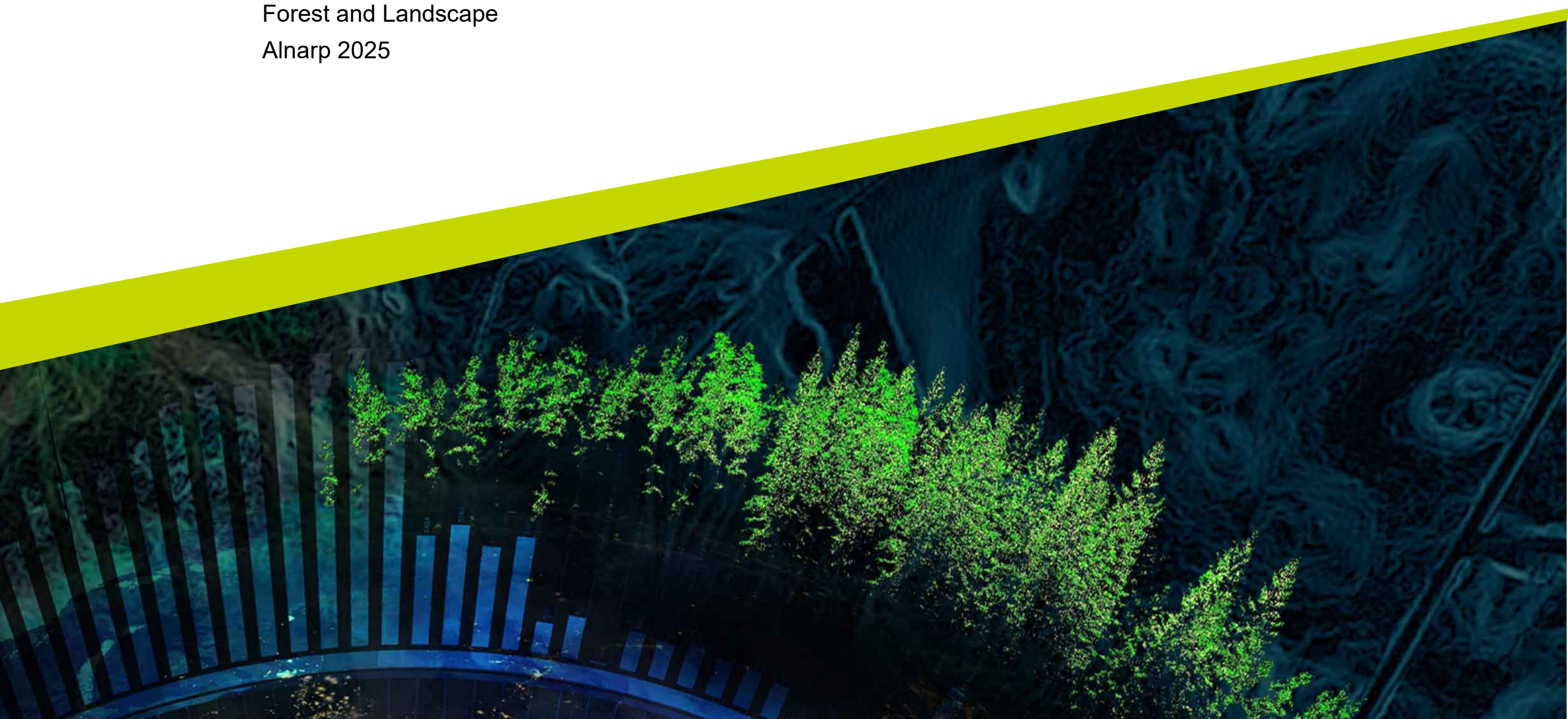
The effects of mechanical site preparation and fertilization on planted birch seedlings in southern Sweden

Hannes Stenström

Independent project • 15 credits
Swedish University of Agricultural Sciences, SLU
Institutionen för Sydsvensk Skogsvetenskap
Forest and Landscape
Alnarp 2025



The effects of mechanical site preparation and fertilization on planted birch seedlings in southern Sweden

Hannes Stenström

Supervisor:	**Karin Hjelm, Swedish University of Agricultural Sciences, SLU, Institutionen för Sydsvensk Skogsvetenskap**
Assistant supervisor:	Kinga Stolarek, Swedish University of Agricultural Sciences, SLU, Institutionen för Sydsvensk Skogsvetenskap
Examiner:	Henrik Böhlenius, Swedish University of Agricultural Sciences, SLU, Institutionen för Sydsvensk Skogsvetenskap

Credits:	15 credits
Level:	First cycle, G2E
Course title:	Independent project
Course code:	EX1012
Programme/education:	Forest and Landscape
Course coordinating dept:	Institutionen för Sydsvensk Skogsvetenskap
Place of publication:	Alnarp
Year of publication:	2025

Keywords:	*Betula pendula,* disc trenching, soil inversion, arginine, seedling establishment

Swedish University of Agricultural Sciences
Institutionen för Sydsvensk Skogsvetenskap

Abstract

The production forestry in southern Sweden is dominated by Norway spruce (*Picea abies*), a species that in recent years has suffered from damage related to climate change. There is a need to diversify the species composition to create more resilient production forests. One suitable species for this is silver birch (*Betula pendula*). Birch is fast growing, produce good quality wood and grows well in the same site conditions as the spruce.

Regardless of species, site preparation and fertilization could be helpful aids to achieve a successful regeneration, giving the seedlings the best possible conditions to grow and survive. There is a lack of research on how to best regenerate birch for quality timber e.g. best site preparation method and effect of early fertilization, two aspects of regeneration investigated in this thesis. Birch seedlings at two sites in southern Sweden were measured and analysed. Both locations had identical experimental plots treated with different site preparation methods, both fertilized and unfertilized.

The results in this thesis show a significant advantage of planting in soil treated with soil inversion compared to disc trenching and untreated control in terms of height growth and survivability. However, soil inversion is expensive, and the economic benefits from better growth and less mortality must be weighed against cheaper site preparation methods for it to be a viable option for forest owners.

Table of contents

List of figures

Abbreviations

Abbreviation	Description
MSP	Mechanical site preparation
SLU	Swedish University of Agricultural Sciences

1. Introduction

Norway spruce (*Picea abies*) has been the most common tree species for production forestry in southern Sweden since the introduction of modern silviculture and changes in land use in the first half of the 20th century (Lindbladh *et al.* 2014). The spruce has great economic potential and well-established management methods, making it an attractive choice for forest owners when regenerating their production forests. However, spruce is sensitive to droughts, making it susceptible to bark-beetle attacks (Linnakoski *et al.* 2017), and warmer winters with unfrozen soils could increase the risk of wind-throw and promote the spreading of root-rot (*Heterobasidion spp.*) (Liziniewicz *et al.* 2022). Other tree species may play a greater role in the future to create more resilient forests, capable of handling a warmer and more unstable climate (Felton *et al.* 2024).

A tree species well suited as an alternative to spruce, both in mixed stands and as monocultures, is the fast-growing pioneer species birch, with the two most common species in Sweden being silver birch (*Betula pendula*) and downy birch (*Betula pubescens*). They have a vast natural range from eastern Sibiria to the coast of Norway and far down in southern Europe (Hynynen *et al.* 2010), and they have a high genetic variation, which makes them tolerate various climate zones and site conditions (Dubois *et al.* 2020). In terms of growth and production, they have different site requirements, where downy birch prefers wet to moist soil and silver birch moist to mesic soil. Silver birch is considered to be the better choice for producing pulpwood or timber since it produces more biomass over time compared to downy birch, as long as the soil is not too wet or nutrient poor (Andersson *et al.* 2005). In this paper, if not stated otherwise, birch means silver birch.

Birch is the most important broadleaf species for production forestry in the Nordic and Baltic countries (Hynynen *et al.* 2010), and in Sweden the total proportion of birch (both species) is around 13% (Nilsson *et al.* 2021). On the most suitable sites, birch can reach a height of 25 meters within 30 years, with the fastest growth between years 10-20. It can potentially reach 30 meters after 50 years before the rate of growth slows and the trees become more susceptible to fungal infections and other damage (Hynynen *et al.* 2010). Genetically improved birch from breeding programs has the potential to reach full height faster, shortening the rotation period and increasing the production of wood. Finland has a longer tradition of selective breeding and related seed orchards of birch than Sweden, and the improved seedling material has shown potential for an increase of up to 30% in stem volume, faster growth and improved stem quality compared to natural birch (Lee *et al.* 2024).

Natural regeneration is still the most common way of establishing new birch forests, and birch can easily regenerate in gaps or clearcuts if there are available seed sources. Managing a naturally regenerated birch forest for quality timber demands a lot of management with intensive pre-commercial thinning and multiple heavy commercial thinnings, leading to a final stem number of 350-400 trees/ha in the mature stand. Being a light demanding species, growing birch in dense stands will cause a decrease in growth (Andersson *et al.* 2005).

Planting is preferred when prioritizing the production of quality timber, and when establishing forests using improved seedlings from nurseries. At sites with heavy competition e.g. fertile former agricultural land, planting is often the only option for a successful regeneration. Manual seeding is also an option for regenerating birch but is rarely used (Hynynen *et al.* 2010).

The most common regeneration method in Sweden (all species included) is planting at 87% (Skogsstyrelsen 2023), and mechanical site preparation (MSP) is usually conducted before planting. This means that 160 000-190 000 ha in Sweden is affected by MSP every year (Sikström *et al.* 2020). There are several MSP methods, including disc trenching and soil inversion (Fig.1). In disc trenching a specialized unit creates furrows in the ground where the excess soil and humus create a ridge by the side of the furrow (berm). In soil inversion a specialized unit digs up a patch of soil and humus, flips it upside down and put it back in the same spot, creating an even planting spot with nutrient rich humus close to the roots of the seedling.

The purpose of MSP is to create the best possible growing conditions for the seedlings by removing the humus layer and exposing the mineral soil underneath. MSP removes competitive vegetation, regulates soil temperature and moisture and prevents pine weevil (*Hylobius abietis*) damage since the pine weevil avoid movement over exposed mineral soil (Wallertz *et al.* 2018). MSP also assist in improving mineralization and nutrient availability in the soil. The practice of MSP has shown an increase of 15-20% in survivability of conifer seedlings and an increase of up to 25% in tree height after 10-15 years (Sikström *et al.* 2020). However, the choice of planting spot within the MSP regardless of type of MSP treatment is also an important factor in regards of growth and survivability.

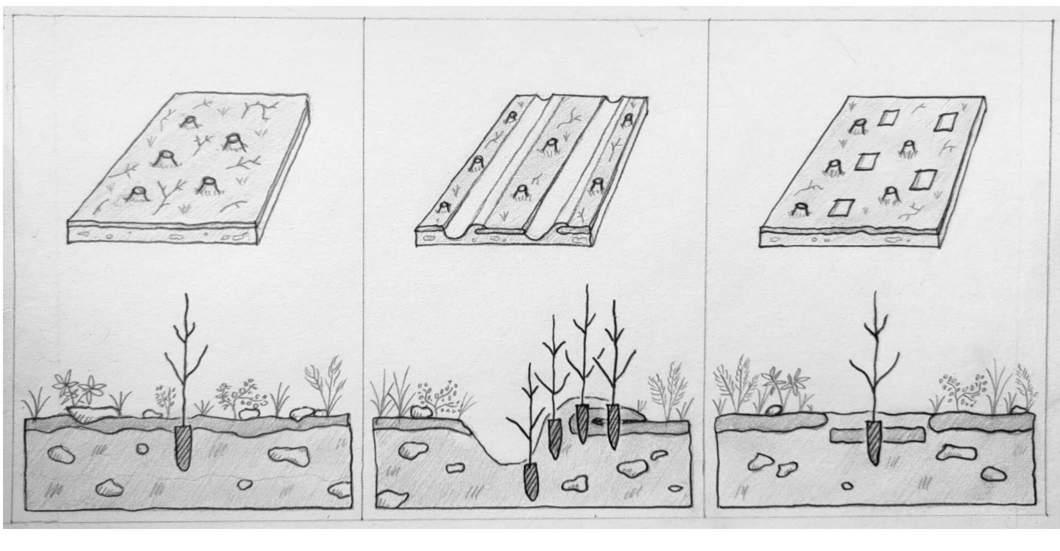


Figure 1. Illustrations of MSP methods, untreated soil (left), disc trenching (middle) and soil inversion (right). Illustrations by: Hannes Stenström after original by RM Rytter.

In a study in which soil moisture, planting spot, and growth and mortality of Norway spruce (*Picea abies*), Scots pine (*Pinus sylvestris*), and birch (*Betula pendula)* were investigated, large variations were observed between the species regarding successful planting spots. In general, the spruce preferred an elevated planting spot and the birch a lower (closer to available water), with the pine being least specific (Nordin *et al.* 2023).

Another method to improve the growth and survival of seedlings is the use of fertilizers, e.g. arginine. Arginine is an organic amino acid and source of nitrogen found naturally in the soil. In plants, most nitrogen is stored as arginine (Luoranen & Saksa 2024). When used as a fertilizer, arginine is crystalized with phosphate in granules (Häggström *et al.* 2023) that are placed in the planting hole or container were it slowly release nitrogen to the seedlings. The purpose of fertilization is to give the seedling an early increase in growth and root development, making it more resistant to damage and capable of competing with other vegetation. There are also observations of quicker mycorrhizal colonization in the roots of conifer-seedlings when fertilized with organic nitrogen (Luoranen & Saksa 2024). In one experiment where seedling of Scots pine, Norway spruce and birch where treated with a small dose of arginine, the results showed a significant positive effect on height growth and survivability in all three species (Häggström *et al.* 2023). But more research and experiments regarding regeneration of birch are needed e.g. site preparation methods and fertilization, two aspects of regeneration investigated in this thesis.

1.1 Aim and scope

This thesis investigated the growth and survivability of planted birch seedlings at two locations in southern Sweden, Tönnersjöheden and Asa. Both locations included three plots, one untreated control, one treated with disc trenching and one treated with soil inversion. All three plots also had a fertilized section where the seedlings were treated with arginine at the time of planting. The seedlings planted in untreated soil, disc trenching and soil inversion were compared to each other, and the fertilized seedlings were compared with the unfertilized seedlings. Data of height growth, diameter growth and mortality were imported into a statistical software (SAS) to determine if the differences were significant or not.

The hypotheses for this thesis were: (1) that growth and survivability are higher in the seedlings growing in the soil treated with disc trenching or soil inversion compared to the untreated control, (2) that the difference in growth and survivability of the seedlings planted in disc trenching and soil inversion treatments are negligible, and (3) that the fertilized seedlings have increased growth and higher survivability compared to the unfertilized seedlings.

2. Method

2.1 Birch plantation experiment

The “Clearcut age experiment Birch” is an ongoing research project initiated by SLU, comprised of four site locations (Tönnersjöheden, Asa, Siljanfors and Vindeln). The aim of the experiment is to study the regeneration of birch e.g. growth, mortality and different kinds of damage, in relation to time of planting, site preparation and fertilization.

All plots in the experiment were established on land of recently clear-cut conifer forests. All plots have the same layout (Fig. 2) in one 18x18m square per treatment type: untreated soil (as control), disc trenching and soil inversion. Nine rows of nine seedlings were planted in each square, with the last three rows fertilized with arginine. Rows one, four and seven were planted in spring 2023, rows two, five and eight in summer 2023 and rows three, six and nine in autumn 2023.

The squares were not fenced, but the seedlings were treated with Trico (fatty acids from sheep) and freezing tape (as mechanical protection) at the shoot tips to repel browsers. The site preparation was done with an excavator and resembles the work done by bigger machinery in operational forestry and the slash was removed from the experimental plots prior to MSP.

In this thesis only data from Tönnersjöheden and Asa was analysed and presented. Tönnersjöheden is located outside Halmstad and Asa outside Växjö, both in the southern part of Sweden.

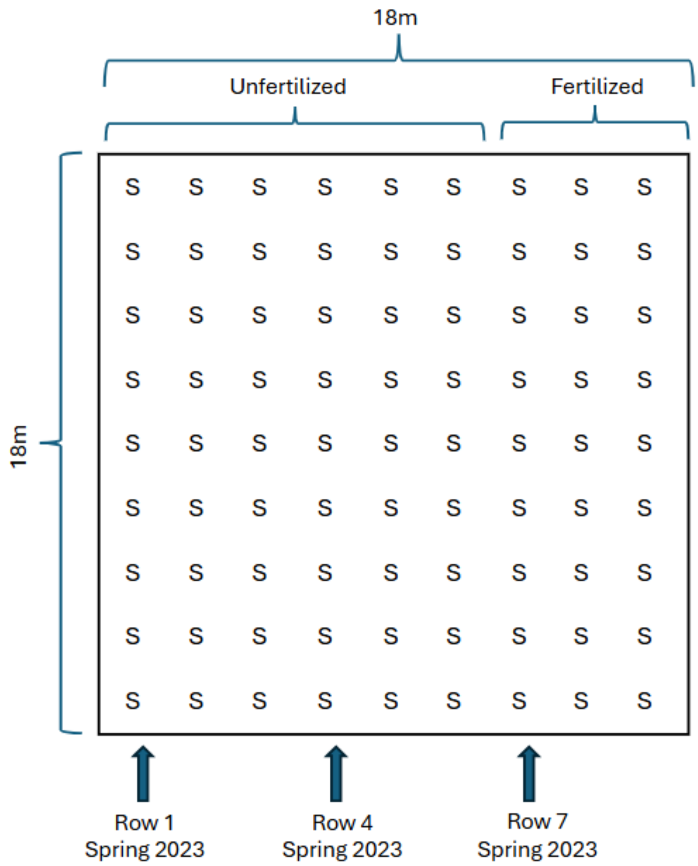


Figure 2. Illustration of the plot design used for all treatments in the "Clearcut age experiment Birch", with the rows planted in 2023 and measured for this paper highlighted with arrows. S=seedling.

2.2 Data collection

At each site (Tönnersjöheden and Asa) all seedlings, both fertilized and unfertilized, planted in spring 2023 in untreated soil, soil treated with disc trenching and soil treated with inversion, were measured and inspected. Data regarding height (cm), stem diameter (mm) and mortality (pcs) were entered into an Excel-sheet for further analysis and comparison with data from previous years (provided by a representative of "Clearcut age experiment Birch"). All measurements and visual inspections were conducted on site in the beginning of April 2025.

A two-meter folding rule was used for height measurements by placing the ruler next to the seedling and measuring the distance from ground level to the top of the leading shoot. A digital Kellen calliper was used to measure the stem diameter just above ground level; on multi-stem seedlings the most dominant shoot was measured. Data regarding mortality was collected by visual inspection e.g. clearly dead or missing seedlings.

2.3 Analysis and presentation of data

The data was imported into the statistical software SAS (SAS 9.4, SAS Institute, Cary, N.C., USA) to determine the statistical significance in height, diameter and mortality between the different MSP methods and between the fertilized and unfertilized seedlings.

In SAS an Anova (mixed model) analysis was performed with “site” (Tönnersjöheden and Asa) being set as a random factor. Factors “MSP” (untreated control, disc trenching and soil inversion) and “fertilization” (yes or no) was set as fixed. Since there were three MSP factors, a Tukey test was performed to determine the differences between the different methods.

The data was also imported into Excel and compared with the data from previous years. All graphs and tables were generated in Excel.

3. Results

3.1 Height

As seen in Figure 3, the mean height of the seedlings planted in the plots treated with soil inversion were higher than in the untreated control and in the plots treated with disc trenching.

In spring 2025 the height of the seedlings planted in soil inversion was significantly higher ($p<0.0001$) in comparison to the untreated control and disc trenching. There was no significant difference between untreated control and disc trenching ($p=0.8037$) or between the fertilized and unfertilized seedlings ($p=0.0566$).

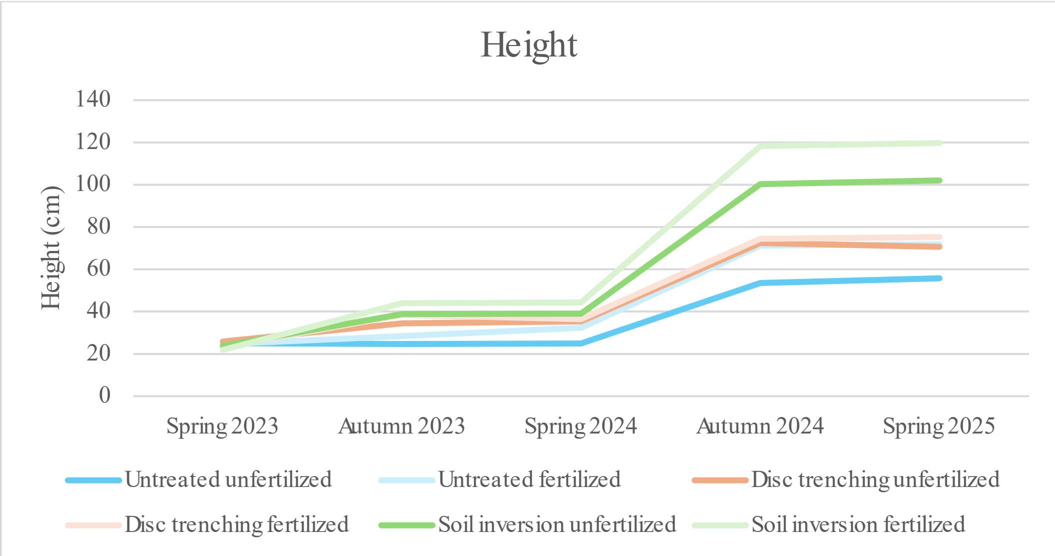


Figure 3. Height of the birch seedlings, both fertilized and unfertilized, in untreated control, disc trenching and soil inversion.

3.2 Diameter

As seen in Figure 4, the diameter growth was larger in the seedlings planted in the plots treated with soil inversion than in the untreated control and the plots treated with disc trenching. The difference between the untreated control and disc trenching was negligible. The diameter of the fertilized seedlings was larger compared to the unfertilized seedlings.

In spring 2025, the difference in diameter in the seedlings planted in soil inversion was significantly larger ($p<0.0001$) in comparison to untreated control and disc trenching. There was no significant difference ($p=0.7799$) between untreated control and disc trenching.

There was a significant difference ($p=0.0031$) between the fertilized and unfertilized seedlings.

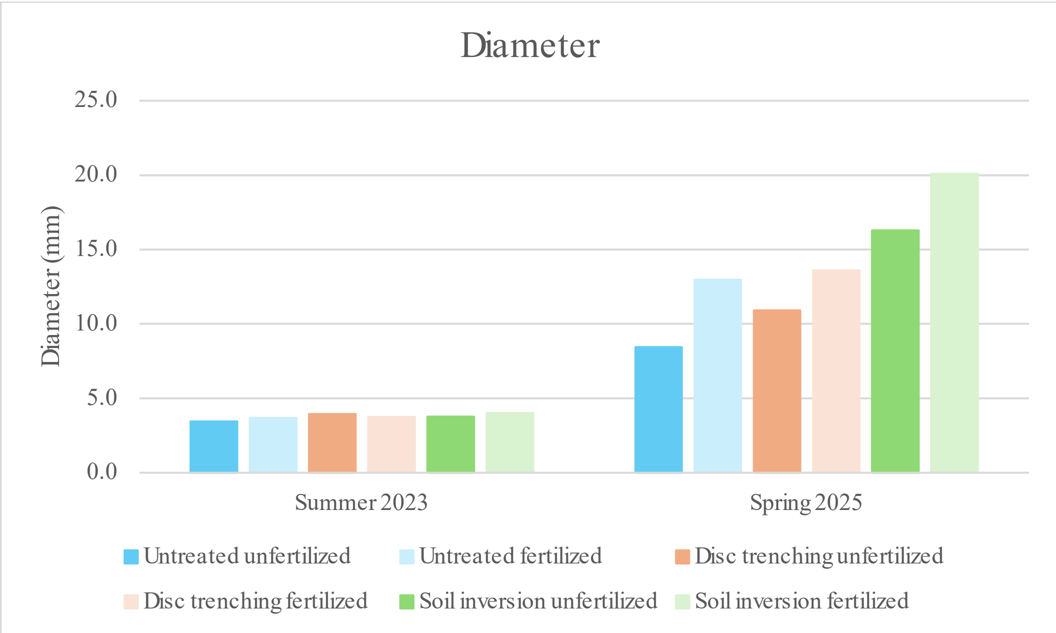


Figure 4. Diameter of the birch seedlings, both fertilized and unfertilized, in untreated control, disc trenching and soil inversion.

3.3 Mortality

As seen in Figure 5, there was a difference in mortality between all three plot treatments: soil inversion, disc trenching and the untreated control. Soil inversion had the least dead or missing seedlings, and the untreated control had the most.

In spring 2025, the difference in mortality of seedlings planted in the different MSP treatments was significant (control – disc trenching p=0.0126, control – soil inversion p=0.0003, disc trenching – soil inversion p=0.0162).

There was no significant positive effect from fertilization on the survivability of the seedlings (p=0.6396).

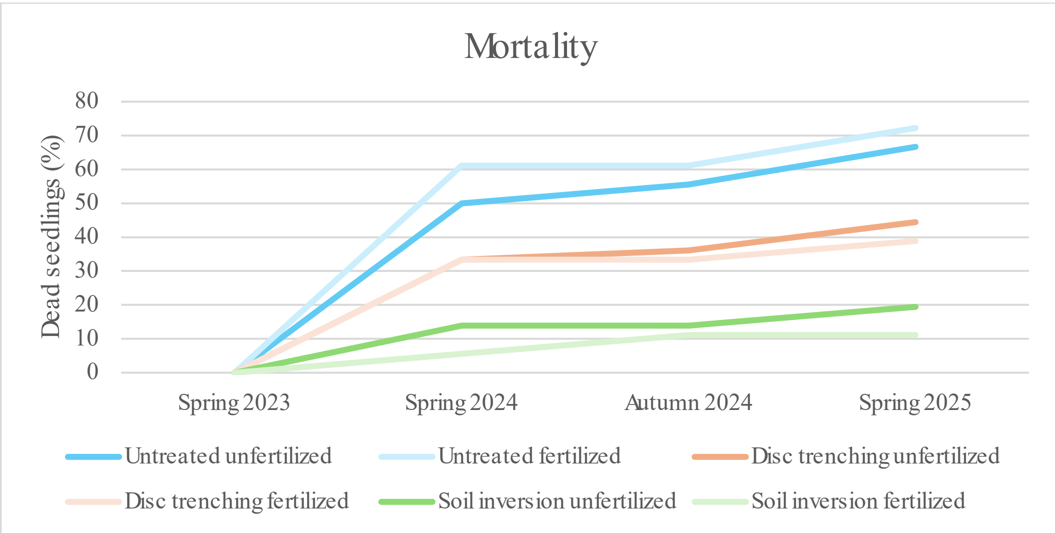


Figure 5. Mortality of the birch seedlings planted in untreated control, disc trenching and soil inversion from spring 2023 to spring 2025.

4. Discussion

The height growth was significantly higher in the plots treated with soil inversion. This could be because soil inversion produces a flat and even planting spot, not high enough to dry out and not low enough to be waterlogged. It seems like birch seedlings are sensitive to the dry conditions of a high planting position on top of a mound (Nordin *et al.* 2023), a condition that also can be found at the top of the ridges after disc trenching but not in soil inversion. Another reason for the better growth in the plots treated with soil inversion could be competition from other vegetation, especially grasses. An example was the plot treated with disc trenching in Tönnersjöheden, where grasses grew in the furrows around the seedlings, while the plots treated with soil inversion still had an area of bare mineral soil surrounding most of the seedlings (personal observation).

Another benefit of soil inversion is the addition of humus underneath the top layer of mineral soil (from the inverted patch of soil) which adds available nutrients near the roots of the seedlings. Furthermore, soil inversion only affects a fraction of the ground area compared to disc trenching, since it is carried out in patches instead of continuous rows, making it a good and less intrusive option from an environmental and recreational perspective.

The diameter growth was also significantly better in the plots treated with soil inversion compared to untreated control and disc trenching. This was not surprising since the diameter growth is usually related to height growth. However, many of the seedlings have had their top shoot damaged at some point, forcing them to resprout or become low and bushy with disproportionate large diameter in relation to height. In earlier inventories (unpublished data) of the plots it is stated that weevils (*Hylobius* and *Strophosoma*) are the main reason for the damage (Stolarek 2025), but since birch also is a preferred source of forage for deer and moose (Ara *et al.* 2022) it is likely that the seedlings were browsed during previous years.

The results of fertilization with arginine was not conclusive, in other field testing the results have varied and other factors like MSP treatment, planting spot, and abundance of browsing animals or insects may play a bigger role than fertilization regarding growth and survivability (Häggström *et al.* 2023). More field trials and experiments with birch seedlings are needed before reaching any definite conclusions. The result in this thesis showed a significant positive effect of fertilizing birch seedlings with arginine in diameter growth, but no significant effect on height growth. One possible explanation for this could be browsing animals impeding the development of the top shoot and forcing the seedlings, fertilized or not, to develop a new top shoot and/or grow sideways instead of upwards. Diameter growth is not impeded in the same way as height growth by browsing animals since new year-rings are added to the stem even if the seedling is browsed.

Most of the dead seedlings at both sites were gone from the plots, which makes it hard to determine the cause of death. Both experimental sites were established on clear-cuts of former conifer forests, known to attract the pine weevil (Nordlander *et al.* 2023) and even though they prefer to feed on the bark of conifers (Löf *et al.* 2004) they feed on broadleaves as well. There were signs of browsing on the surviving seedlings which could mean that the dead and missing seedlings were browsed to the extent that they died. Another cause of mortality could be water availability, birch seedlings have shown a sensibility to dry soil conditions (Nordin *et al.* 2023) and poor planting spots (e.g. high up on ridges), but in general, the planting spots did not seem poor at any of the sites or plots (personal observation). There was no significant difference in mortality between the fertilized and unfertilized seedlings, however it is possible that competing vegetation could take advantage of the additional nutrients provided by the fertilization and have a negative effect on the seedlings.

The results showed better growth and less mortality in plots treated with soil inversion, but the possible benefits must be weighed against the increased cost and time-consumption of soil inversion compared to disc trenching. Soil inversion requires specialized equipment, and the unit needs to stop at each patch to be able to place the inversed soil back in the same spot. The cost of soil inversion is roughly 4200 SEK/ha compared to disc trenching at 2200-2400 SEK/ha (Sikström n.d.) and the economic benefits from higher growth and survivability must outweigh the additional cost of this type of MSP.

Although not tested significantly, there seemed to be differences between the two sites (Tönnersjöheden and Asa) in terms of height growth and mortality, however, the trends seen in height, diameter and mortality in relation to MSP treatment were the same at both sites. There are many possible reasons for the differences in growth and mortality between the two sites e.g. nutrient and water availability, mean temperature, precipitation and abundance of damaging agents like insects or browsing animals. It was surprising to see that the seedlings in Asa, with lower mean annual temperature and less precipitation (SMHI 2024), had better growth and less mortality than Tönnersjöheden. The fact that the seedlings in Tönnersjöheden to a greater extent had a bushy appearance (from earlier damage to top shoot and branches) could indicate that a higher browsing pressure or abundance of weevils and other insects is the reason for the lower growth rate and greater mortality.

Since the data in this paper is derived from only two experimental sites with a relatively small number of seedlings at each site, it is important to be cautious when drawing general conclusions about the benefits or drawbacks of different MSP treatments and fertilization when planting birch. There are also differences between the two sites regarding growth and mortality, further emphasising the need to be critical to the results.

Initially, data regarding type of damage and severity of damage were to be included in the paper, in previous records from inventories 2023 and 2024 it was suggested that much of the damage to top shoots and branches were caused by weevils (*Hylobius* and *Strophosoma*). At the time of data collection in spring 2025 there were no fresh damage to the seedlings to help assess the type of damage and it was concluded that the older damage could originate from browsing as well as from insects. Because of the difficulty in determining the type of damaging agent, this was not included in this thesis.

4.1 Conclusion

The height and diameter growth were significantly higher in the spots treated with soil inversion compared to the untreated control and disc trenching. There was no significant difference between the untreated control and disc trenching. Fertilization with arginine had a significant positive effect on diameter growth but not on height growth (but very close), possibly because of browsing or insect damage on the seedlings. The differences in mortality between the untreated control and disc trenching, and between disc trenching and soil inversion was significant, with soil inversion having the least mortality and untreated control having the most.

It is difficult to draw any wider conclusions from this experiment because only two experimental sites were investigated (Tönnersjöheden and Asa) and because the number of seedlings at each site were quite small. There is a need for more experiments and field tests on how to successfully regenerate birch. For soil inversion to be a viable MSP option for forest owners, the benefits must be greater than the additional cost compared to other MSP treatments.

References

Andersson, R., Andersson, M. & Sverige, S. (2005). *Björk, asp och al : föryngring, skötsel och naturvård*. Skogsstyrelsens förlag.

Ara, M., Maria Felton, A., Holmström, E., Petersson, L., Berglund, M., Johansson, U. & Nilsson, U. (2022). Pre-commercial thinning in Norway spruce-birch mixed stands can provide abundant forage for ungulates without losing volume production. *Forest ecology and management,* 520, 120364. https://doi.org/10.1016/j.foreco.2022.120364

Dubois, H., Verkasalo, E. & Claessens, H. (2020). Potential of Birch (Betula pendula Roth and B. pubescens Ehrh.) for Forestry and Forest-Based Industry Sector within the Changing Climatic and Socio-Economic Context of Western Europe. *Forests,* 11(3), 336. https://www.mdpi.com/1999-4907/11/3/336

Felton, A., Seidl, R., Lindenmayer, D.B., Messier, C., Löf, M., de Koning, J.H.C., Ranius, T., Cleary, M., Hedwall, P.-O., Torres García, M.T. & Felton, A.M. (2024). The choice of path to resilience is crucial to the future of production forests. *Nature ecology & evolution,* 8(9), 1561-1563. https://doi.org/10.1038/s41559-024-02473-x

Häggström, B., Lutter, R., Lundmark, T., Sjödin, F. & Nordin, A. (2023). Effect of arginine-phosphate addition on early survival and growth of Scots pine, Norway spruce and silver birch. *Silva fennica (Helsinki, Finland : 1967),* 57(2). https://doi.org/10.14214/sf.22013

Hynynen, J., Niemistö, P., Viherä-Aarnio, A., Brunner, A., Hein, S. & Velling, P. (2010). Silviculture of birch (*Betula pendula Roth* and *Betula pubescens Ehrh*.) in northern Europe. *Forestry (London),* 83(1), 103-119. https://doi.org/10.1093/forestry/cpp035

Lee, D., Siipilehto, J., Miina, J., Niemistö, P., Haapanen, M., Hynynen, J. & Huuskonen, S. (2024). Site index and stand characteristic models for silver birch plantations in southern and central Finland. *Forest ecology and management,* 563, 121998. https://doi.org/10.1016/j.foreco.2024.121998

Lindbladh, M., Axelsson, A.-L., Hultberg, T., Brunet, J. & Felton, A. (2014). From broadleaves to spruce – the borealization of southern Sweden. *Scandinavian journal of forest research,* 29(7), 686-696. https://doi.org/10.1080/02827581.2014.960893

Linnakoski, R., Forbes, K.M., Wingfield, M.J., Pulkkinen, P. & Asiegbu, F.O. (2017). Testing projected climate change conditions on the endoconidiophora polonica / Norway spruce pathosystem shows fungal strain specific effects. *Frontiers in plant science,* 8, 883. https://doi.org/10.3389/fpls.2017.00883

Liziniewicz, M., Barbeito, I., Zvirgzdins, A., Stener, L.-G., Niemistö, P., Fahlvik, N., Johansson, U., Karlsson, B. & Nilsson, U. (2022). Production of genetically improved silver birch plantations in southern and central Sweden. *Silva fennica (Helsinki, Finland : 1967),* 56(1), 1. https://doi.org/10.14214/sf.10512

Löf, M., Isacsson, G., Rydberg, D. & Welander, T.N. (2004). Herbivory by the pine weevil (*Hylobius abietis L.*) and short-snouted weevils (*Strophosoma melanogrammum Forst.* and *Otiorhynchus scaber L.*) during the conversion of a wind-thrown Norway spruce forest into a mixed-species plantation. *Forest ecology and management,* 190(2), 281-290. https://doi.org/10.1016/j.foreco.2003.10.027

Luoranen, J. & Saksa, T. (2024). The effects of arginine phosphate (ArGrow® Granulat) on growth of Scots pine and Norway spruce seedlings planted in varying soil layer structures simulating site preparation. *Forestry (London),* 97(4), 580-589. https://doi.org/10.1093/forestry/cpad060

Nilsson, P., Roberge, C., Fridman, J. & Sveriges lantbruksuniversitet. Institutionen för skoglig, r. (2021). *Skogsdata : aktuella uppgifter om de svenska skogarna från SLU Riksskogstaxeringen 2021 Tema: Fjällskogen*. SLU Institutionen för skoglig resurshushållning.

Nordin, P., Olofsson, E. & Hjelm, K. (2023). Within-site adaptation: Growth and mortality of Norway spruce, Scots pine and Silver birch seedlings in different planting positions across a soil moisture gradient. *Silva fennica (Helsinki, Finland : 1967),* 57(3), 1. https://doi.org/10.14214/sf.23004

Nordlander, G., Björklund, N., Hellqvist, C., Nordenhem, H., Liziniewicz, M. & Hjelm, K. (2023). Trap catch data are poor predictors of damage caused by pine weevil (*Hylobius abietis*) to conifer seedlings. *Forest ecology and management,* 537, 120968. https://doi.org/10.1016/j.foreco.2023.120968

Sikström, U., Hjelm, K., Kjersti Holt, H., Timo, S. & Kristina, W. (2020). Influence of mechanical site preparation on regeneration success of planted conifers in clearcuts in Fennoscandia – a review. *Silva fennica (Helsinki, Finland : 1967),* 54(2). https://doi.org/10.14214/sf.10172

Sikström, U.G., Helena; Hjelm, Karin; Hajek, Jörgen; Sundblad, Lars Göran; Skogforsk (n.d.). *Kalkyler beståndsanläggningskedjor – några exempel*. Skogssällskapet. https://www.skogssallskapet.se/download/18.706b03641584ebf5394229f3/1478869703062/1314-129+165-9+Bilaga+3+Kalkyler.pdf

Skogsstyrelsen (2023). *Statistik om återväxternas kvalitet*. https://www.skogsstyrelsen.se/statistik/skogsskotsel/atervaxternas-kvalitet/ [20-05-2025]

SMHI (2024). *data/temperatur-och-vind/temperatur/ars--och-manadsstatistik*. https://www.smhi.se/data/temperatur-och-vind/temperatur/ars--och-manadsstatistik [28-04-2025]

Stolarek, K. (2025). *Seedlings and regeneration procedures for future birch forests. Unpublished thesis.* Institutionen för sydsvensk skogsvetenskap. Swedish University of Agricultural Sciences.

Wallertz, K., Björklund, N., Hjelm, K., Petersson, M. & Sundblad, L.-G. (2018). Comparison of different site preparation techniques: quality of planting spots, seedling growth and pine weevil damage. *New forests,* 49(6), 705-722. https://doi.org/10.1007/s11056-018-9634-8

Approved students' theses at SLU can be published online. As a student you own the copyright to your work and in such cases, you need to approve the publication. In connection with your approval of publication, SLU will process your personal data (name) to make the work searchable on the internet. You can revoke your consent at any time by contacting the library.

Even if you choose not to publish the work or if you revoke your approval, the thesis will be archived digitally according to archive legislation.

You will find links to SLU's publication agreement and SLU's processing of personal data and your rights on this page:

- https://libanswers.slu.se/en/faq/228318

☒ YES, I, Hannes Stenström, have read and agree to the agreement for publication and the personal data processing that takes place in connection with this

☐ NO, I/we do not give my/our permission to publish the full text of this work. However, the work will be uploaded for archiving and the metadata and summary will be visible and searchable.