Examensarbeten **2012:15**
Institutionen för skogens ekologi och skötsel

Influence of prescribed burning and/or mechanical site preparation on stand stem density and growth of Scots pine stands above the Arctic Circle:

– Results 9-19 years after stand establishment

Photo: Mikael Sörhult

Mikael Sörhult

Sveriges Lantbruksuniversitet Jägmästarprogrammet
Examensarbete i skogshushållning, 30 hp, avancerad nivå A2E ISSN 1654-1898
Handledare: Urban Bergsten, SLU, Inst för skogens ekologi och skötsel
Examinator: Göran Hallsby, SLU, Inst för skogens ekologi och skötsel Umeå 2012

Examensarbeten 2012:15

Institutionen för skogens ekologi och skötsel

Influence of prescribed burning and/or mechanical site preparation on stand stem density and growth of Scots pine stands above the Arctic Circle:

– Results 9-19 years after stand establishment

Inverkan av hyggesbränning och/eller maskinell markberedning av stamantal och tillväxt av tallbestånd ovanför polcirkeln:

– Resultat 9-19 år efter beståndsetablering

Mikael Sörhult

Nyckelord / *Keywords:*
Sådd; Plantering; Pinus sylvestris; Skador; Föryngringskostnader; Simulering /
Direct seeding; Planting; Pinus sylvestris; Damages; Regeneration cost; Simulation

ISSN 1654-1898 Umeå 2012

Sveriges Lantbruksuniversitet / *Swedish University of Agricultural Sciences*
Fakulteten för skogsvetenskap / *Faculty of Forest Sciences*
Jägmästarprogrammet / *Master of Science in Forestry*
Examensarbete i skogshushållning / *Master degree thesis in Forest Management*
EX0706, 30 hp, avancerad nivå / *advanced level* A2E

Handledare / *Supervisor*: Urban Bergsten
SLU, Inst för skogens ekologi och skötsel / *SLU, Dept of Forest Ecology and Management*
Examinator / *Examiner:* Göran Hallsby
SLU, Inst för skogens ekologi och skötsel / *SLU, Dept of Forest Ecology and Management*

Abstract

Prescribed burning was commonly used for site preparation in Sweden to establish new forests until the 1960's, when mechanical scarification was introduced. During recent decades the interest in prescribed burnings has increased again, mainly due to certifications of forestry stating that 5% of the regeneration areas should be burned on dry and mesic soils.

The objective of the study was to evaluate actual influence of prescribed burning compared to other site preparation on stand stem density, growth parameters and tree damages for Scots pine (*Pinus sylvestris* L.) after direct seeding and planting. The study also attempts to simulate growth until first thinning. Regeneration cost per hectare and tree was also evaluated for the different treatments.

The study was performed in 2011 in Norrbotten County, above the Arctic Circle. There were four different treatments; mechanical scarification following direct seeding with or without prescribed burning and planting following prescribed burning or mechanical scarification. Stands were selected pair-wise (four pairs for each regeneration method), for each site treatment within the two regeneration methods and several criteria were used to make the pairs comparable. All stands were established about one to two decades ago.

Direct seeding and mechanical scarification combined with prescribed burning showed after 9 to 16 years a significantly increased tree height and diameter in breast height compared to just mechanical scarification. The corresponding increases in stem volume, tree biomass above ground and stand stem density were as high as 210% m^3sk/ha, 205% kg/ha and 43%/ha, albeit only close to significance on the 5%-level. For planting there were no clear differences in growth parameters and stand stem density between site preparations. Further, site preparation and regeneration method did not affect the degree of damage because of moose, voles and cronartium rust. The cost per established seedling today after direct seeding was only about one third of the cost for planting. To conclude, prescribed burning in combination with mechanical scarification seems clearly advantageous when direct seeding in the harsh areas above the Arctic Circle in Sweden.

Keywords: Direct seeding; Planting; *Pinus sylvestris*; Damages; Regeneration cost; Simulation

Sammanfattning

Hyggesbränning användes allmänt i Sverige vid etablering av ny skog fram till och med 1960-talet när maskinell markberedning introducerades. Under senare decennier har de flesta större skogsföretagen i Sverige blivit certifierade enligt ex. FSC vilket bl.a. medfört åtagandet att 5 % av föryngringsarealen skall brännas på torr och frisk mark och därmed lett till ett förnyat intresse för hyggesbränning.

Syftet med denna studie var att undersöka hyggesbränningens inverkan, jämfört med maskinell markbredning, på stamantal, tillväxtparametrar och skador för tall (*Pinus sylvestris* L.) med sådd och plantering. Dessutom har tillväxten fram till första gallring simulerats för nämnda behandlingar och föryngringskostnader per hektar och träd beräknats för de olika behandlingarna.

Studien är utförd 2011 i Norrbottens län, ovanför polcirkeln. Fyra olika behandlingar har jämförts; sådd efter markberedning på bränd eller obränd mark samt plantering efter hyggesbränning eller efter maskinell markberedning. Bestånd valdes parvis, fyra par för respektive föryngringsmetod. Ett antal kriterier utgjorde grund för att paren skulle kunna jämföras. Bestånden var ungefär anlagda en till två årtionden före studien.

Sådd efter markberedning och hyggesbränning medförde signifikant (5 % -nivån) högre träd och större brösthöjdsdiameter efter 9 till 16 år jämfört med enbart markberedning. Motsvarande ökningar i stamvolym, trädbiomassa ovan mark och stamantal var 210 % m^3sk/ha, 205 % kg/ha och 43 %/ha dock var skillnaderna endast nära signifikans. För plantering fanns inga skillnader mellan markbehandlingarna. Inte heller nivån av skador orsakade av älg, sork eller törskate skiljde sig åt mellan markbehandlingar eller föryngringsmetoder. Kostnaden per etablerad planta idag efter sådd var endast ca en tredjedel av kostnaden för plantering. En övergripande slutsats är alltså att sådder verkar utvecklas betydligt bättre norr om polcirkeln om hyggesbränning och maskinell markberedning kombineras jämfört med om endast maskinell markberedning utförs.

Nyckelord: Sådd; Plantering; *Pinus sylvestris*; Skador; Föryngringskostnader; Simulering

Contents

Introduction

Prescribed burning has been used as site preparation method in forest regeneration in Sweden for several decades. In the 1960's as much as 30 000-40 000 hectare was burned annually (Granström 1991; Kardell 2004). At that time mechanical site preparation was introduced and since then the use of prescribed burning has decreased to a low level (Granström 1991). Reasons for the decrease are that burning requires much labour, i.e. is costly, and that the burning result is weather-dependent. However, under the 1990's prescribed burning received an increased interest in forestry due to nature conservation obligations. According to the certification agreements of FSC about 5% of the regeneration areas for larger landowners should be burned over a five year period (Anon 2010). During recent years the annual area of prescribed burning is therefore as high as around 2 000-3 000 hectares in the certified forestry (Wikars 2006). It is more common in the north part of Sweden compared to southern regions, in most southern Sweden it is not used at all.

Previous studies have shown varying results of prescribed burning on stand development. According to Bergman and Eriksson (1966) Scots pine stands in northern Sweden that were established by planting between 1950-1959 had better height development after prescribed burnings all years except for 1951 in comparison to unburned stands. On the other hand, Huss and Sinko (1969) found lower height development after prescribed burning compared to unburned stands ten years after planting and direct seeding in spite of having an positive effect of burning during the first years after establishment in these stands (Tirén 1953). Selected stands from these studies were re-inventoried by Andersson and Karlsson (1981) at a stand age of 25-30 years and at this age the height development was higher in prescribed burned stands.

Another argument for prescribed burning is that under certain conditions it could improve seedling survival and promote establishment of dense stands. After the burning the ground becomes black which gives a higher absorption of sunlight and thereby an increase of soil temperature (Wikars & Niklasson 2006). Mechanical scarification may also lead to a rise of temperature but in this case it is because of the exposure of mineral soil (Örlander & Gemmel 1989). Another possible advantage with burning is that it eliminates competition from vegetation; one of the most important to reduce in cover is the crowberry (*Empetrum hermaphroditum* Hagerup). Crowberry creates allelopathy and affects germination, survival and growth of Scots pine. Crowberry has a shallow rot system that is sensitive to fire and the coal that is created by burning may bind the poison that crowberry excrete (Zachrisson & Nilsson 1989). Especially in harsh climate of most northern Sweden it could be advantageous to use prescribed burning as a soil treatment when regenerating new forest. According to Eiche (1966) and Eriksson *et al*. (1980) mortality will occur for a very long time after planting or direct seeding in these areas due to the slow growth; seedlings will remain small and suffer from mechanical damage and competition for a long time.

In this work the objective was to quantify the influence on regeneration success and seedling/sapling growth of Scots pine (*Pinus sylvestris* L.) by prescribed burning and/or mechanical scarification in harsh areas above the Arctic Circle in Sweden. The revived interest in prescribed burning during the 1990's due to conservation purposes have made it possible to find stands that have passed the most sensitive phases of development i.e., the stands could be considered established when they have reached an age of at least about a decade.

The following questions have been addressed, with focus on results after about one to two decades:

i) How does prescribed burning, with or without the combination of mechanical scarification and in comparison to just mechanical scarification, affect stand stem density and growth of Scots pine after direct seeding and planting today and until first thinning?

ii) What causes (e.g. damages) could there be to possible differences between treatments in stand stem density?

iii) Are possible differences in growth related to stand stem density or growth rate per individual tree?

iv) What is the regeneration cost per tree when using prescribed burning in comparison to conventional regeneration measures?

Material and methods

This survey study was carried out for the forest company Sveaskog, within Norrbotten County (figure 1) where Sveaskog owns 1 933 000 hectares (Anon 2011a). The Norrbotten County is known for its harsh winters and short summers. The annual mean temperature is about 1 to -2˚C and as low as -3˚C in the mountains. Precipitation is 600 mm per year at the coast and up to 800 mm in the inland. The vegetation periods are from 120 days in the mountains and 150 days at the coast (Anon 2011b).

The field inventories were done for about six weeks in June, August, September and November 2011.

The material is divided into two separate groups with comparisons within and between groups, in total with four different treatments. The first group includes stands that are established by (i) direct seeding after prescribed burning and mechanical scarification and (ii) direct seeding in combination with only mechanical scarification. The second group consists of stands established by (iii) planting after prescribed burning and by (iv) planting after mechanical scarification as soil preparation method. The stands in the study were selected from Sveaskog's land and from privately owned land; all the stands are above the Arctic Circle. Twelve of the stands are in Tärendö and four in Kalix district of Sveaskog (figure 1; table 1).

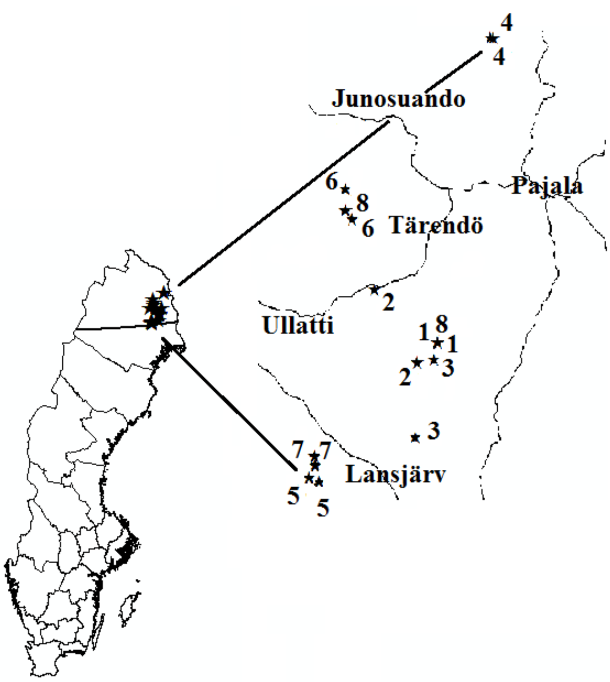

Figure 1. Map of Sweden showing pairs of surveyed stands (nr 1-8) in Norrbotten County, above the north Arctic Circle.

Table 1. Inventoried stands. P.b. is prescribed burning and D.t. is disc trenching.

Reg. method	Pair nr	Name	Age (years)	Soil treatment	Year of soil treatment	Year of seeding/planting	Xcoord.	Ycoord.
Direct seeding	1	Narkaussölkä	16	P.b. + D.t.	1994	1995	7442479	832193
			16	D.t.	1994	1995	7442697	831973
	2	Kompelusvaara	13	P.b. + Patch scarification	1998	1998	7455709	816010
			13	D.t.	1998	1998	7437820	826820
	3	Länsiharju	11	P.b. + D.t.	2000	2000	7438315	831111
			11	D.t.	2000	2000	7419106	826357
	4	Lehtovaaravägen	9	P.b. + D.t.	2002	2002	7518216	845669
			9	D.t.	2002	2002	7518161	846349
Planting	5	Vinakvägen	19	P.b.	1992	1992	7408132	801731
			19	D.t.	1991	1992	7409036	799097
	6	Loukasvuoma	14	P.b.	1995	1997	7480618	808528
			14	Mounding	1997	1997	7473268	810256
	7	Alainenjänkä	10	P.b.	1999	2001	7412592	800733
			10	Mounding	2000	2001	7412113	800733
	8	Nalfaanlehto	10	P.b.	1999	2001	7475306	808528
			10	Mounding	1999	2001	7442479	832193

Stands were selected pair-wise, i.e. for each burned and/or mechanically scarified stand that was direct seeded or planted; a control stand with only mechanical scarification was selected.

Stands were selected with the following criteria as a guide:

1. Established with Scots pine by planting or direct seeding
2. Establishment year the same within pairs
3. Pre-commercial thinning not performed
4. Stand size at least 1 hectare
5. Seeding/planting at least 9 years ago but not more than 20 years ago
6. Site index (HI) not differing more than 1-2 m within pairs
7. Nearest sites that fulfil the criterions of above shall be chosen first

The total area inventoried was about 78 hectares; 109 plots and 3 494 trees where measured. The plots in the stand were randomly layed out with the program Sveaskog sample tool. There were from five to eight plots in the stands, depending on stand size (5 plots; <6 ha, 6 plots; 6-9 ha, 7 plots; 10-16 ha, 8 plots; >16 ha). Sample plot area was 100 m^2, each plot was given X- and Y-coordinates. Plot's ending up at the stand edge was re-sampled 20 steps into the stand.

On each plot the number of trees of each tree species was registered and for each tree the following was registered:

a) Diameter at breast height (1.3 meters above soil surface)
b) Tree height
c) Artificially- or naturally-established
d) Damages

To find stand and plots ArcMap and a GPS-device was used. Calliper was used for measuring diameter (cm) and a height stick was used to measure tree height (dm). Damages because of moose (*Alces alces L.*), vole (*Clethrionomys glareolus* Schr.) and cronartium rust (*Cronartium flaccidum* Alb. & Schw.) were measured for Scots pine. Threshold was if the tree was considered to have a damage that would clearly affect growth and/or stem quality in the future. The moose damage was registered if the trees had obvious signs in forms of stem break, bark and shoots damages. Visual signs of cronartium rust were required to register this type of damage.

Plot and tree data were compiled with Microsoft Excel and subsequent statistical analyses was done using Minitab (paired t-test, linear regression) for stand stem density, diameter at breast height, tree height, stem volume, tree biomass above ground and damages. Input value was pair-wise level. ANOVA with Tukey's test was used to evaluate differences between treatments in establishment costs. The level of significance was chosen to $p \leq 0.05$. The calculations of stem volume was made according to Andersson (1954); cubic functions were used for small trees in north of Sweden. Biomass was calculated according to Ahnlund Ulvcrona (2011) for the Scots pine. To analyse the cost for different establishment method basic data from Sveaskog representing 2011 was used (table 2). Simulations of development until first thinning was made for the four most typical stands, one for each combination of soil treatment and regeneration method using Heureka StandWise software, input value were plot-level. Different levels of pre-commercial thinning (PCT) were compared; no PCT, for all four stands, PCT 3 000 and PCT 2 000 for only direct seeding and PCT 1 000 stems/ha for all four stands. PCT were assumed to be performed after five years. Stem volume and biomass were predicted to the age of 60.

Table 2. Establishment costs (SEK), from Sveaskog Norrbotten County 2011.

Method	Cost	Number/amount/ per ha and size	Other information
Planting	2.06:-/pl	2 300 pl/ha	Incl. work and planting costs
Mech. seeding	3 800:-/ha	0.3 kg/ha	Incl. mechanised scarification and seed costs
Manual seeding	2 700:-/ha		Incl. work and seeds (excl. mechanised scarification)
Disc trenching	1 550:-/ha		
Mounding	1 550:-/ha		
Patch scarification	1 550:-/ha		
Prescribed burning	3 000:-/ha	< 10 ha	Incl. preparation, execution and supervision
	2 500:-/ha	10-30 ha	—“ —
	2 000:-/ha	> 30 ha	—“ —

Results

Stand stem density, growth parameters and damages

According to the paired t-test for direct seeding, there were significant or close to significant differences between prescribed burning in combination with mechanical scarification in comparison with just mechanical scarification, for stand stem density, tree characteristics and stem volume/biomass per ha (table 3). In relative values there were 43% more trees, a higher stem volume and biomass per ha of about 210% m^3sk/ha and 205% kg/ha. There were no significant differences between the two treatments when damages because of moose, vole and cronartium rust were analysed (table 3).

Table 3. Results for direct seeding of artificially establish Scots pine after 9 to 16 years. Stand stem density, growth parameters and tree damages after prescribed burning (P.b.) and mechanized scarification as well as for only scarification. P-value is for paired t-test (4 pairs of stands were compared).

	P.b. & Mech. scarification			Mech. scarification			
Parameter	Mean	StDev	SE Mean	Mean	StDev	SE Mean	P-value
Stand stem density[a] (st/ha)	4095	1020	510	2861	1445	722	0.078
Tree height (m)	1.661	0.513	0.257	1.127	0.458	0.229	0.023
Tree diameter (dbh/cm)	1.737	0.606	0.303	0.988	0.419	0.21	0.03
Stem volume[b] (m^3sk/ha)	4.64	2.85	1.43	1.5	0.95	0.47	0.058
Biomass[c] (kg/ha)	3118	1824	912	1021	629	314	0.052
Moose damage (%)	16.2	24.2	12.1	26.6	28.1	14.1	0.674
Vole damage (%)	1.19	1.44	0.72	1.74	2.08	1.04	0.732
C. rust damage (%)	0.244	0.187	0.094	0.279	0.559	0.279	0.906

[a]Sveaskog used mechanized seeding in these stands with a seed dosage of 0.3 kg/ha.

[b]Stem volume calculated according to Andersson (1954); cubic function.

[c]Biomass calculated according to Ahnlund Ulvcronas (2011).

For planting there were far from significant differences between prescribed burnt and mechanical scarification irrespective of studied parameter. However, there were trends of increases in tree height (23% m), diameter at breast height (48% cm), stem volume (87% m^3sk/ha) and biomass (70% kg/ha). Neither significant differences, nor any trends, could be seen for results regarding damages because of moose, vole and cronartium rust (table 4).

Table 4. Results for planting of artificially establish Scots pine after 10 to 19 years. Stand stem density, growth parameters and tree damages after prescribed burning (P.b.) as well as for only mechanical scarification. P-value is for paired t-test (4 pairs of stands were compared).

	P.b.			Mech. scarification			
Parameter	Mean	StDev	SE Mean	Mean	StDev	SE Mean	P-value
Stand stem density[a] (st/ha)	1622	650	325	1687	545	273	0.771
Tree height (m)	2.567	0.999	0.5	2.088	0.558	0.279	0.273
Tree diameter (dbh/cm)	3.88	2.42	1.21	2.62	1.03	0.51	0.227
Stem volume (m^3sk/ha)	7.64	6.21	3.1	4.08	2.59	1.29	0.162
Biomass (kg/ha)	4188	3136	1568	2469	1478	739	0.163
Moose damage (%)	16.1	20.1	10	12.1	5.7	2.8	0.765
Vole damage (%)	4.6	4	2	27.1	37.8	18.9	0.279
C. rust damage (%)	4.44	4.43	2.21	4.92	7.96	3.98	0.938

[a]The planting was done with 2 300 plants per hectare.

Stem volume and biomass with respect to stand stem density

Each 100 m^2-plot in the study (direct seeding 53 plots; planting 56 plots), were used to relate stem volume and biomass to stand stem density (figure 2). As shown by linear regression there was a clear trend for direct seeding that stem volume and biomass per ha increased with increasing stand stem density and that prescribed burning entailed higher values irrespective of stem density. A somewhat similar trend was seen for planting as well but the variation was much higher with very low R^2.

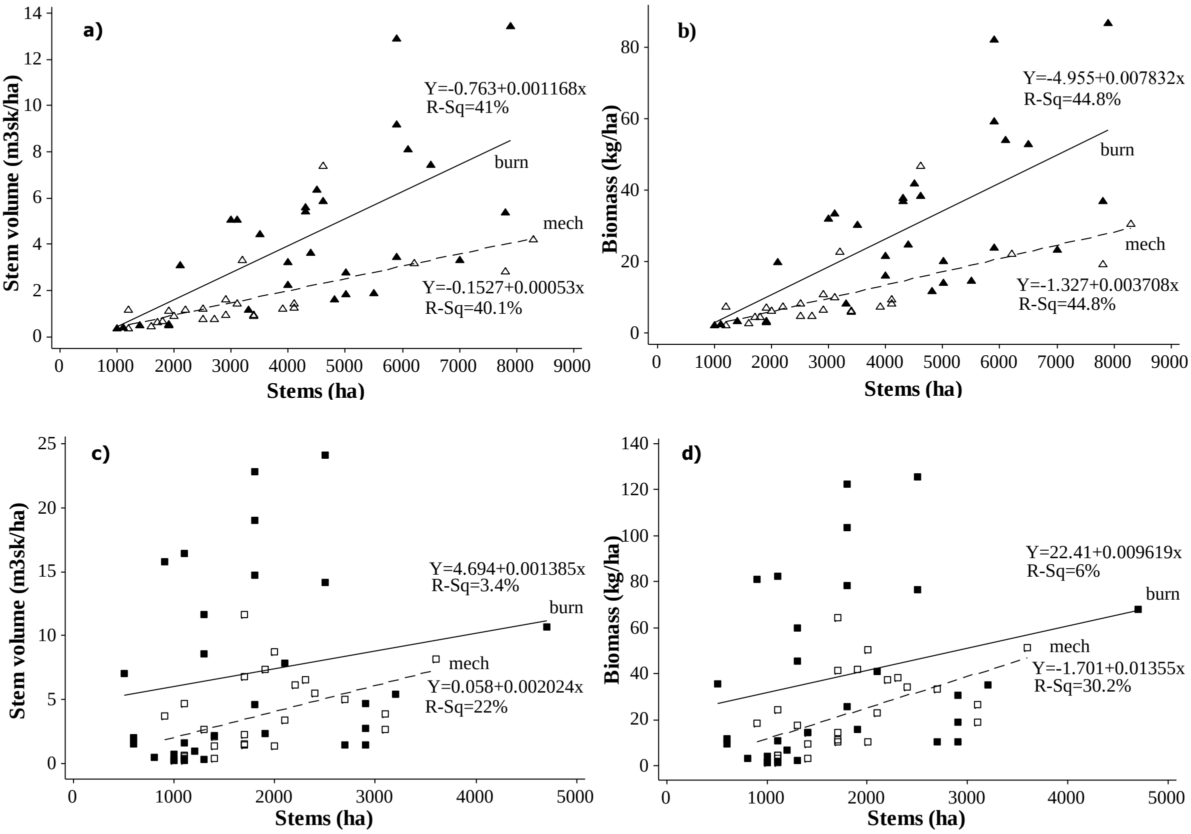

Figure 2. Stem volume (a, c) and biomass (b, d) after direct seeding and after planting (a, b and c, d). Filled symbols: prescribed burning and mechanical scarification (direct seeding) or prescribed burning (planting). Unfilled symbols: mechanical scarification.

Costs

Cost per established plant at the time of inventory was about the same for the two treatments of direct seeding despite the fact that the cost per hectare was much higher at the establishment occasion for prescribed burning (table 5). Neither for planting was there any significant difference between the two soil treatments. The difference between the two regeneration methods was high and significant though, with planting about threefold more expensive.

Table 5. Costs (SEK) for different site preparations and establishment methods at establishment and for established plants/saplings at the time of inventory. ANOVA with post hoc-test Tukey; p≤0.05. P.b. is prescribed burning.

Soil preperation	Regeneration method	Cost per hectare	Cost per established plant	Tukey
P.b. & Mech. scarification	Direct seeding	6 425	1.63	A
Mech. scarification	—"—	3 800	1.55	A
P.b.	Planting	7 363	5.00	B
Mech. scarification	—" —	6 288	4.05	B

Simulation of stand development

According to the simulation of Heureka StandWise, direct seeding and mechanical scarification combined with prescribed burning development highest to a height of 7 m (maximum height limit in this Heureka-run), 30; 35 years old, planting with mechanical scarification the lowest values of volume and biomass above ground (figure 3). Prescribed burning with direct seeding and without PCT should give the highest stem volume and biomass compared to all other treatments up to an age of 60 years. PCT down to 3 000 and 2 000 stems/ha could only be performed with direct seeding due to the number of stems available. For a radical PCT down to 1 000 stems/ha, planting and mechanical scarification showed the highest values, and direct seeding with mechanical scarification without prescribed burning the lowest values of stem volume and biomass (figure 4).

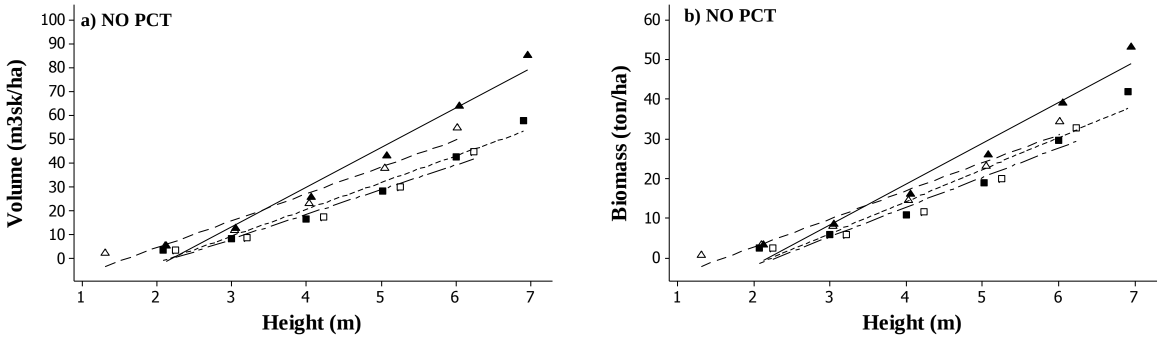

Figure 3. Stem volume and tree biomass above ground with respect to tree height for no PCT. Triangles are direct seeding and squares are planting. Filled symbols are prescribed burnings (and mechanical scarification for direct seeding) and unfilled are mechanical scarification.

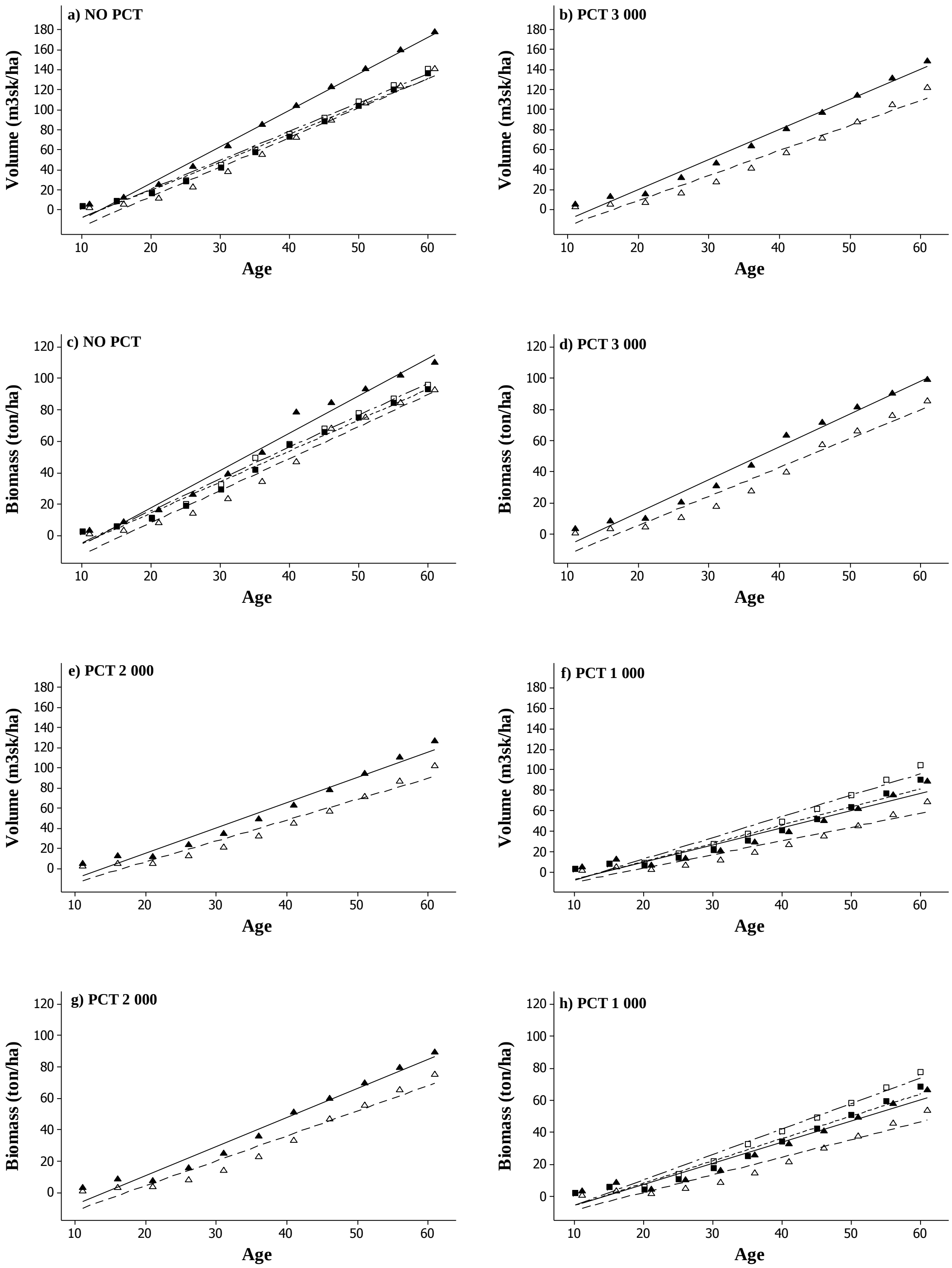

Figure 4. Stem volume and tree biomass above ground with respect to age for no PCT, 3 000, 2 000 and 1 000 stems/ha. Triangles are direct seeding and squares are planting. Filled symbols are prescribed burnings (and mechanical scarification for direct seeding) and unfilled are mechanical scarification.

Discussion

Stand stem density tended to be higher after direct seeding and prescribed burning in combination with mechanical scarification compared to direct seeding after just mechanical scarification. Old experiments have showed similar positive result of increased emergence/survival thanks to prescribed burnings when direct seeding (Tirén 1952) but in the old experiments it was manual screefing after burning. Similar results as found here of positive effects on growth by prescribed burning in combination with direct seeding has been shown earlier by Tirén (1953) and according to Huss and Sinko (1969) this effect is more clear on poor sites. One difference with this study compared to older studies is that here the effect of burning seems to be higher. In this study there was no clear effect of prescribed burning on stand stem density/survival and tree growth with planting, contrary to the findings of Bergman and Eriksson (1966).

According to the simulation with Heureka StandWise prescribed burning and mechanical scarification in combination with direct seeding develop would produce the highest values of stem volume and biomass up to the age of 60 years with no PCT, 3 000 and 2 000 stems. In comparison to for PCT down to 1 000 stems/ha the differences are quite big but further analyses could be needed as well as further tests of the quite new Heureka StandWise.

Damages from moose, vole and cronartium rust were documented in every stand, on every plot. No significant differences in damage frequency could be found between different treatments. Damage by moose is probably more related to the habitat than to the regeneration method and site preparation. Factors that are known to influence are local climate, vegetation composition, food supply and snow depth (Ekman *et al*. 1992). The critical browsing height is 1.5-3.5 m according to Lavsund (2003) and it should be noted that the unburned treatment of direct seeding had often not reached the critical browsing height and these stands could therefore be more exposed to moose damage in the coming years. However, there could still be an advantage of having high stand stem densities as a security to avoid getting stands with very few stems/ha because of moose damage (Lavsund 2003). Damages from vole could also be linked to the habitat, e.g. the presence of grass, which also has been shown earlier by Hansson (1983), vole damage is more frequent on richer soils and especially with ground covering with grass (Edstedt & Torung 1978). Neither the damages of cronartium rust were related to soil preparation; this is also shown by Tillberg (2010).

Why this work shows positive effects (significant or close to significant) on stand stem density and growth parameters of prescribed burning in combination with mechanical scarification and direct seeding probably depends on several factors. Prescribed burnings (Wikars & Niklasson 2006) and mechanical scarification removes competing vegetation on soil surface. Prescribed burning increases temperature (Wikars & Niklasson 2006) and reduces abundance of crowberry (Zachrisson & Nilsson 1989). During fire part of the bound nitrogen in vegetation and humus is lost; the ash that is left contains no nitrogen but many other important nutrients such as phosphorus, potassium, calcium and magnesium (Ring 1997). Prescribed burning maybe works best in harsh climate and on poor shrub sites (Huss & Sinko 1969), and for direct seeding, because emerging seeds and germinants are dependent on having a certain threshold temperature to develop and grow. Too low temperatures cannot be substituted by increased time for germination (Winsa 1995).

However, also in less harsh areas prescribed burning and mechanical scarification in combination with microsite preparation and direct seeding has shown a clear positive effect on survival (Hofsten & Weslien 2000).

Damages at early establishment may explain the different results between direct seeding and planting. Planting after prescribed burning includes a risk of attacks by pine firefungus (*Rhizina undulata* Fr.). This fungus causes mortality of planted seedlings 2-6 years after prescribed burning (Hagner 1962). Direct seeding is less vulnerable, no damage comes the first year, but it is also less sensitive coming years (Hagner 1960). Pine weevil (*Hylobius abietis* L.) can be a problem, according to Hofsten and Weslien (1999) when planting, it is very important that the clearcut area is allowed to rest for at least two years after burning, otherwise much pine weevil damage could be expected. In my material for planting and prescribed burning, three of four stands have two years of rest; this may have affected the result.

The cost at establishment for direct seeding is increased when adding prescribed burning (2 625 SEK/ha), but thanks to the higher survival the cost per established seedling at the time of inventory was about the same as for just mechanical scarification (table 5). The improved growth is of course an extra benefit. For planting there were no clear significant positive effects on stand stem density and growth of prescribed burning. This means that the higher costs of prescribed burning at the burning occasion, compared to mechanical scarification, still remains if costs per established seedlings at the time of inventory are concerned. However, the costs for burning might vary quite much. According to Hörnsten *et al.* (1995) the cost of prescribed burning in 1990-1994 varied between 1 000-3 000 SEK/ha depending on stand size. Later studies from Westerberg (1997) showed cost to between 1 300-4 000 SEK/ha. For Sveaskog the average cost were from 2 000-3 000 SEK/ha (table 2).

Since this work is a survey done in stands that are established by operational forestry the variation in most parameters within and between stands is quite high and the reasons for the variation cannot be analysed. Further, the work is made as a master thesis with limited access to time and the number of replicates is therefore low. Since big variation is a bigger problem when having few replicates, for further analyses of the data material it should be advantageous to include inventory results from more stands.

Conclusions

It can be concluded that prescribed burning in combination with mechanical scarification and direct seeding of Scots pine in northern areas of Sweden could be used to establish, to a low cost, dense stands with comparably high growth of stem volume and biomass.

Acknowledgements

I want to thank my supervisor Urban Bergsten from Swedish University for Agricultural Sciences (SLU) for help and great support.

Thanks to Magnus Ekström and Sören Holm for support with the statistics.

I also want to thank Sveaskog for allowing me to perform this thesis, particularly Hans Winsa for active participation in planning and evaluations, Johan Lundbäck for help with finding stands, Arto Hiltunen for support and delivering required materials.

References

Ahnlund Ulvcrona, K. 2011. Effects of silvicultural treatments in young Scots pine-dominated stands on potential for early biofuel harvest. Dissertation. Umeå. Swedish University of Agricultural Sciences. ISBN: 978-91-576-7623-8.

Andersson, B. & Karlsson, S. 1981. Hyggesbränningens effekt på tallens produktion – Analys av 25-30 år gamla försök belägna i Norrland. Sveriges Lantbruksuniversitet. Institutionen för skogsskötsel. Umeå. Examensarbete.

Andersson, S.-O. 1954. Funktioner och tabeller för kubering av småträd. Meddelanden från Statens Skogsforskningsinstitut 44:12, 29 s.

Anon. 2010. Svensk skogsbruksstandard enligt FSC med SLIMF-indikatorer. Forest Stewardship Council. Uppsala.

Anon, 2011a. Sveaskog. Homepage. [online] (2011-03-25) Available: http://www.sveaskog.se/om-sveaskog/skogsinnehav/areal-per-lan/ [2011-03-25]

Anon. 2011b. SMHI. Homepage. [online] (2011-02-15) Available: http://www.smhi.se/klimatdata [2011-02-15]

Bergman, F. & Eriksson, L. G. 1966. Resultat av inventering av kulturer anlagda under åren 1950 – 1959 i höjdlägen över 400 M Ö.H. Mo och Domsjö AB, Skogliga försöksförvaltningen Björna.

Edstedt, K.-G. & Torung, D. 1978. Sork- och älgskador på Pinus contorta. Sveriges Lantbruksuniversitet. Skogsvetenskapliga fakulteten. Umeå. Examensarbete i viltekologi.

Eiche, V. 1966. Cold damage and plant mortality in experimental provenance plantations with Scots pine in northern Sweden. Studia Forestalia Suecica. Nr 36. Stockholm: Skogshögskolan Stockholm.

Ekman, H. Hermansson, N. Petterson, J. O. Ruckler, J. Steen, M. Ståfelt, F. 1992. Älgen, Djuret-Skötseln och Jakten. Spånga. Svenska jägarförbundet. ISBN 91-7118-702-2.

Eriksson, G. Andersson, S. Eiche, V. Ifver, J. & Persson, A. 1980. Severity index and transfer effects on survival and volume production of Pinus sylvestris in northern Sweden. Studia Forestalia Suecica. Nr 156. Uppsala: Swedish University of Agricultural Sciences.

Granström, A. 1991. Elden i människans tjänst. In: Skog & forskning nr. 4:6-12. Sveriges skogsvårdsförbund.

Hagner, M. 1960. Rotmurklan – en aktuell skadegörare på brända hyggen. Norrlands Skogsvårdsförbunds Tidskrift 7:81-96.

Hagner, M. 1962. Några faktorer av betydelse för rotmurklans skadegörelse. Norrlands Skogsvårdsförbunds Tidskrift s. 245–270.

Hansson, L. 1983. Viltskadorna, speciellt sorkskadorna, beroende av proviens hos *Pinus contorta*. Uppsala. Sveriges Lantbruksuniversitet. Institutionen för viltekologi. Rapport 1983 01 15.

Hofsten, H. & Weslien, J-O. 1999. Föryngring av brända hyggen i Norrland med hänsyn till Snytbagge. Skogforsk. Arbetsrapport nr 416.

Hofsten, H. & Weslien, J-O. 2000. Föryngring av brända hyggen i Norrland med hänsyn till snytbagge – två-årsresultat. Skogforsk. Arbetsrapport nr 443.

Huss, E. & Sinko, M. 1969. Effekt av hyggesbränning. Sveriges Skogsvårdsförbunds Tidskrift 385-424.

Hörnsten, L. Nohlgren, E. Aldentun, Y. 1995. Brand och bränning – en litteraturstudie. Skogforsk, Redogörelse. Nr 9, 1995.

Kardell, L. 2004. Svenskarna och skogen del 2. Från baggböleri till naturvård. Skogsstyrelsen förlag, Jönköping.

Lavsund, S. 2003. Skogsskötsel och älgskador i tallungskog. Resultat från skogforsk. Nr 6, 2003.

Ring, E. 1997. Bränning – effekter på luft, mark och vatten. Skogforsk resultat. Nr 17, 1997.
Tillberg, E. 2010. Skador orsakade av törskatesvamp på ungskog av tall Pinus sylvestris samt förekomst av kovall i hygges-brända respektive mekaniskt markberedda bestånd. Sveriges Lantbruksuniversitet. Institutionen för skogen ekologi och skötsel. Umeå. Examensarbete.
Tirén, L. 1952. On experiments in sowing pine and spruce seed in northern Sweden. Meddelande från statens skogsforskningsinstitut. Band 41. Nr 7.
Tirén, L. 1953. Comparisons between different sowing methods. Meddelande från statens skogsforskningsinstitut. Band 43. Nr 9.
Westerberg, D. 1997. Bränning – metoder och kostnader 1996/97. Skogforsk resultat. Nr 19, 1997.
Wikars, L.-O. & Niklasson, M. 2006. Behovet av brand i skogen.
Wikars, L.-O. 2006. Åtgärdsprogram för bevarande av brandinsekter i boreal skog. Rapport 5610. Naturvårdsverket, Stockholm.
Winsa, H. 1995. Effects of seed properties and environment on seedling emergence and early establishment of *Pinus sylvestris* L. after direct seeding. Dissertation. Umeå. Swedish University of Agricultural Sciences. ISBN: 91-576-4982-0.
Zackrisson, O. & Nilsson, M.-C. 1989. Allelopati och dess betydelse på. svårföryngrade skogsmarker. - Skogsfakta. Biologi och skogsskötsel 59: 1-6.
Örlander, G. & Gemmel, P. 1989. Markberedning, Sveriges Skogsvårdsförbunds Tidskrift 3.

Used software

ESRI ArcMap 10.0
Heureka StandWise 1.7.1.5
Microsoft Excel 2010
Minitab 16.1
Sveaskog Provyteverktyg 1.1

SENASTE UTGIVNA NUMMER

2011:15 Författare: Steve Fahlgren
Kärnvedsbildning i tall (*Pinus sylvestris* L.) – Startålder samt årlig tillväxt i Västerbotten

2011:16 Författare: Kerstin Frid
Kan hamlingen fortleva som tradition? – en studie över hamlingens historia och framtid i Bråbygden med omnejd

---

2012:1 Författare: Liisa Sars
Röjningsformens effekt på den yttre kvalitén hos björkstammar när beståndet närmar sig första gallring

2012:2 Författare: Daniel Timblad
Kvalitet och skador i tallungskog efter röjning vid olika stubbhöjder

2012:3 Författare: Aron Sandling
Epiphytic lichen flora in a boreal forest chronosequence

2012:4 Författare: Elsa Bengtsson
Leaf area index in *Vittelaria Paradoxa* parklands in Burkina Faso estimated by light interception and leaf sampling

2012:5 Författare: Tomas Jansson
Estimation of reindeer lichen biomass by image analysis

2012:6 Författare: Axel Eriksson
Röjningsformens effekt på tallens (*Pinus sylvestris* L.) tillväxt och kvalitetsegenskaper

2012:7 Författare: Björn Henningsson
Inverkan av röjning och gödsling på mikrofibrillvinkeln i tallens (*Pinus sylvestris* L.) ungdomsved

2012:8 Författare: Sophie Casetou
The inter- and intra- specific variability of charcoal traits in boreal ecosystems

2012:9 Författare: Andreas Hagenbo
Allelopathic effects of Calluna vulgaris on Pinus sylvestris and Populus tremula

2012:10 Författare: Mikael Öhman
Utveckling av ett GIS-verktyg för selektion av bränningstrakter – en studie genomförd på SCA-skogs marker inom Medelpads skogsförvaltning

2012:11 Författare: Klara Joelsson Hedemyr
Soil organic carbon and infiltrability in relation to distance from trees (*Vitellaria paradoxa*) with and without termite mounds in a parkland of central Burkina Faso

2012:12 Författare: Felicia Olsson
Tame animals in the wilderness – livestock grazing around summer farms in Jämtland, boreal Sweden 1800-2011

2012:13 Författare: Jonas Sjödin
Undersökning av självspridning av contortatallen i norra Sverige

2012:14 Författare: Nils Henriksson
Measuring N uptake and transport in *Pinus sylvestris* to estimate mycorrhizal transfer efficiency. A tracer/fertilizer experiment in northern Sweden

Hela förteckningen på utgivna nummer hittar du på www.seksko.slu.se