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Effects of mechanical site preparation on the growth of Jack Pine (Pinus banksiana)

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EFFECTS OF MECHANICAL SITE PREPARATION ON THE GROWTH OF JACK PINE (*PINUS BANKSIANA*)

By

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An Undergraduate Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Honours Bachelor of Science in Forestry

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ABSTRACT

The boreal forest in Canada provides a large volume of timber for Canadians and other countries year after year and effective silviculture is the key to sustainable harvesting. Site preparation can be a critical step in effective regeneration of sites, as it alters soil conditions and vegetative competition. The objective of this study is to be able to determine the difference in mean annual increment (MAI) in terms of height growth and root collar width that mechanical site preparation has in Jack Pine regenerated stands. A total of six regenerated harvest blocks, three with site preparation and three without site preparation, that were a mix of four and five years old were studied within the Lakehead Forest around the city of Thunder Bay in the fall of 2017. The data collected (Height in cm/yr. and root collar diameter in cm/yr.) from these plantations was analyzed using SPSS Statistics, which provided descriptive statistics and a univariate ANOVA. For the data to be significant, a 95% confidence level was required (P=0.05). The significance value for height and root collar diameter values between treatments was 0.824 and 0.755, respectively. This shows that the null hypothesis of this study was correct in that there was no significant increase in height in the site prepared sites from the non-site prepared sites. This could be due to a number of limitations involved with studying the boreal forest, and if this study was to be repeated, more consideration of these limitations could lead to different results.

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INTRODUCTION AND OBJECTIVE

The early stages of regenerating harvested forest can be the most critical point in creating a future forests composition and structure. There are several different identified silvicultural intensities in the province of Ontario, each requiring a certain degree of involvement in regenerating harvested stands. Natural regeneration, which is the least expensive silvicultural intensity, is often not enough to create the desired future forest unit. To better control the future forest unit, regeneration will often involve artificial planting of the desired tree species (Thiffault, 2016).

Several different species are commonly used to regenerate Northwestern Ontario's boreal forests, each of which require varying growing conditions to grow. Jack Pine (*Pinus banksiana*) is one of these commonly planted species and is often planted in areas that where deciduous competition is high (Bull et al 1996). Jack Pine are a shade intolerant species, and so planting gives these seedlings an advantage over the competition. Creating favourable conditions for tree growth can have a large impact on seedling growth, and regeneration of a site via artificial planting is only successful if seedling survival is sufficient. To create proper site conditions, some form of site treatment before and/or after planting can be used to create microsites, and control soil conditions as well as competing vegetation. Site preparation can involve a number of different techniques, such as the use of herbicides, mechanical equipment, or prescribed burning (OMNRF, 2015).

Mechanical site preparation in the form of disc trenching is a commonly used technique in Northwestern Ontario, which involves a skidder pulling two discs approximately six feet apart across an area to create continuous lines of microsites. Disc trenching is economically suitable to the large clear-cuts associated with harvesting in Northwestern Ontario, while at the same time accomplishing the objectives of site preparation (Wilks, 2004).

The purpose of this study will be to examine the growth impacts that site preparation might have on the first few years of growth in artificially planted Jack Pine. The information gathered from this study could potentially be used to determine if site preparation can be used for the purpose of encouraging Jack Pine establishment. From this study, traits such as mean annual increment (MAI) of height and root collar width, general tree health, and competition levels within each tree will be examined across a number of different sites, and across two different site treatment types. From this data, significant differences obtained will be used to determine whether type of site treatment has had a significant impact on tree growth.

OBJECTIVE

The objective of this study is to be able to determine the difference in mean annual increment (MAI) in terms of height growth and root collar width that mechanical site preparation has in Jack Pine regenerated stands.

HYPOTHESIS

My hypothesis (Ha) is that the Jack Pine trees planted in the site prepared blocks will have a higher MAI in height as well as root collar width than the Jack Pine planted in the blocks with no site preparation. The null hypothesis is that the Jack Pine trees planted in the site prepared blocks will have the same MAI in height as well as root collar width as the Jack Pine planted in the blocks with no site preparation

LITERATURE REVIEW

The Forest Management Guide to Silviculture in the Great Lakes-St. Lawrence and Boreal Forests of Ontario (2015) gives a large amount of useful information that can be used when determining what silvicultural treatments should be used in stands across the boreal forest. In a clear-cut stand, direct planting of Jack Pine should be used when competition from hardwoods will be moderate to high, as this will give Jack Pine seedlings more of an advantage over vegetative competition. If organic matter or "duff" layers exceed 10cm, mechanical site preparation should be used in order to create an appropriate number of microsites across the stand. When planting, seedling densities should be from 800-2100 seedlings per hectare, this range being dependent on number of available microsites for Jack Pine. After planting, vegetative competition should be monitored to determine if competition should be reduced, as Jack Pine is a shade intolerant species. This can be accomplished through a variety of silvicultural methods; however, the application of herbicides is commonly used due to its cost efficiency and effectiveness.

Although Jack Pine is the most commonly aerially seeded species in Northern Ontario, it is commonly planted because forest managers often have a difficult time establishing a stand that represents the conifer dominated stand that was harvested. These plantations allow managers to manipulate the species composition in a stand at a critical time in stand establishment, which is the first few years after harvest. With direct planting, other silvicultural prescriptions may be required to maintain a successful plantation; however, it plays a large role in obtaining a sustainable timber supply, as well as biodiverse forest in the years to come (Bull et al, 1996).

Planting stock type can be a large factor in the establishment of a plantation in the boreal forest, as the transplanting stresses from nursery to forest are quite tough on seedlings. These stresses can either kill seedlings soon after planting, or significantly slow growth of the seedlings, which could allow these seedlings to be outcompeted by other vegetation. Because of this, it is important that transplanted seedlings have the proper frost hardiness, drought resistance, root growth capacity, crown form, and shoot/root ratio in order to maximize the chances of success when establishing a plantation (Burdett, 1990).

Although clear-cutting in Northern Ontario emulates many physical patterns of natural disturbances such as fires, it does not achieve the important conditions that Jack Pine has adapted to in order to be a pioneer species on open sites. In the history of the boreal forest, fire has been a major disturbance, and a driver of forest succession, as it would "reset" stands back to the first stages of succession when it burned forests. These fires would create receptive seedbeds to allow for the seeds, coming from the serotinous cones of Jack Pine, to quickly establish themselves in stands with no canopy. This is important because the removal of Jack Pine stands via harvesting will require silvicultural methods, such as site preparation, in order to establish Jack Pine stands, as they would have re-established themselves naturally post-fire (Chrosciewicz, 1990).

There are many different types of mechanical site preparation methods, also known as scarification, and the decision on which one will be used can be based on the economics of the scarifier, the layout of the planting site, and the desired planting patterns on the site. A common scarification method used in clear-cuts in Northern Ontario is that of disc-trenching, which uses a pair of discs dragged behind a skidder, or other suitable machines, to scrape away two continuous lines of organic matter, exposing the mineral soil underneath. This works well in Northern Ontario because of the large sized clear-cuts, making faster work of both the scarification and planting of the site. One risk associated with disc trenching however, is that too much mineral soil can be removed by the discs, reducing the number of microsites rather than increasing it (Wilks, 2004).

A number of objectives can be accomplished through disc trenching, each of which will aid in quickly establishing a healthy plantation. One effect of disc trenching is the reduction in vegetation in the trenches created due to the scraping of the soil surface. Also, due to the three different planting positions disc trenching makes available, planters are able to plant trees in positions that run on a scale from most wet to most dry (Von der Gonna, 1992). Furthermore, disc trenching can alter soil conditions in order to control frost heaving (Goulet, 2000), soil temperature, and available oxygen in the soil (Mackenzie, 1999).

Herbicide applications in forests across Canada have been used for over 30 years although it has been causing much debate on whether or not they are environmentally friendly or if they are decreasing biodiversity. One reason that herbicides are still used today is because they are more efficient at controlling unwanted vegetation in Jack Pine stands. Wagner et al (2005) write about a study done on herbicide treatments done in Northeastern Ontario on the effect of herbicide treatments on Black Spruce (*Picea* *mariana*). Five consecutive herbicide applications using glyphosate, each a year apart, increased stem volumes of trees by 111 – 477 percent when compared to a similar stand that was left untreated. While this study is not on Jack Pine, and 3-4 more treatments of herbicides are used than normally would be, the co-relation of herbicide treatment with tree growth can be used to help understand why herbicides are such a useful tool in forestry.

In a study done by Burgess et al (2010), the authors show that the early growth of Jack Pine improves significantly with the use of silvicultural disturbances. In this study, the effects of scarification, fertilization, and herbicide application on four different species in New Brunswick, including Jack Pine. While this study was not geographically close to Northern Ontario, the species in the study, with the exception of Norway Spruce (*Picea abies*), are all commonly grown in Northern Ontario. Of the four species, Jack Pine responded the most positively to the silvicultural treatments, as it was able to grow rapidly in response to the treatments, which allowed it to outcompete other vegetation.

Another study done on Jack Pine done by Longpré et al (1994) examined the effects on growth that Trembling Aspen (*Populus tremuloides*) and Paper Birch (*Betula papyrifera*) had on Jack Pine in Northwestern Quebec. Again, this study is not done in Northern Ontario; however, the species are commonly grown in both provinces. In this study it was determined that Paper Birch had the most significant impact on the growth of Jack Pine, not in terms of height but rather in terms of diameter, where diameter of Jack Pine increased when grown on the same site as paper birch. This increase in diameter growth of the species can be attributed to the increased light availability when grown with Paper Birch.

The result of a forest treated using mechanical site preparation, direct planting of conifers, and aerial herbicide spray, which is classified as intensive silviculture, has been shown to often create a mixed-wood forest between the one or two conifer species that have been planted, and the hardwoods that are native to the site. This is shown in a study done by Bell & Newmaster (2002) where the objective of the study was to resolve statements that intensive silviculture of conifer species in the boreal forest would gradually result in monocultures being spread across the landscape. This study focused on white spruce (*Picea glauca)* plantations; however, it would not be inaccurate to assume that Jack Pine (*Pinus banksiana*) would have similar results. In this study, factors such as areas missed by silvicultural disturbances as well as hardwood species re-establishing themselves in the site a few years after silvicultural disturbance, as well as other factors, all contributed to a fairly diverse forest across the regenerated area. This study aids in helping the reader understand what kind of forest a silviculturalist might be striving to obtain when using intensive silvicultural intensities.

Furthermore, a study done by Mallik (2003) speaks towards how not using intensive silviculture methods could rather result in deciduous monocultures, due to the method of harvest used in the boreal forest. Clear-cuts are almost always the harvest method used in the boreal forest and can be said to emulate natural disturbances due to the patterns that they create across the landscape. However, this method creates conditions favourable to the regeneration of deciduous species and makes it very difficult for conifers to naturally regenerate due to a number of reasons. These reasons are all related more or less to the lack of fire in the stand, which conifers like Jack Pine are very well adapted to and are considered pioneer species because of their ability to quickly establish themselves in a stand after fire. This lack of conifer regeneration can be balanced with the use of different silvicultural intensities.

METHODS AND MATERIALS

The process of carrying out this project began with selecting harvest blocks across the Lakehead Forest that have the required tree species, as well as the required site treatment type. For this study Jack Pine blocks were studied, and two types of treatments were studied, which include:

1. Site prepared, planted, and tended
2. Planting and tending only

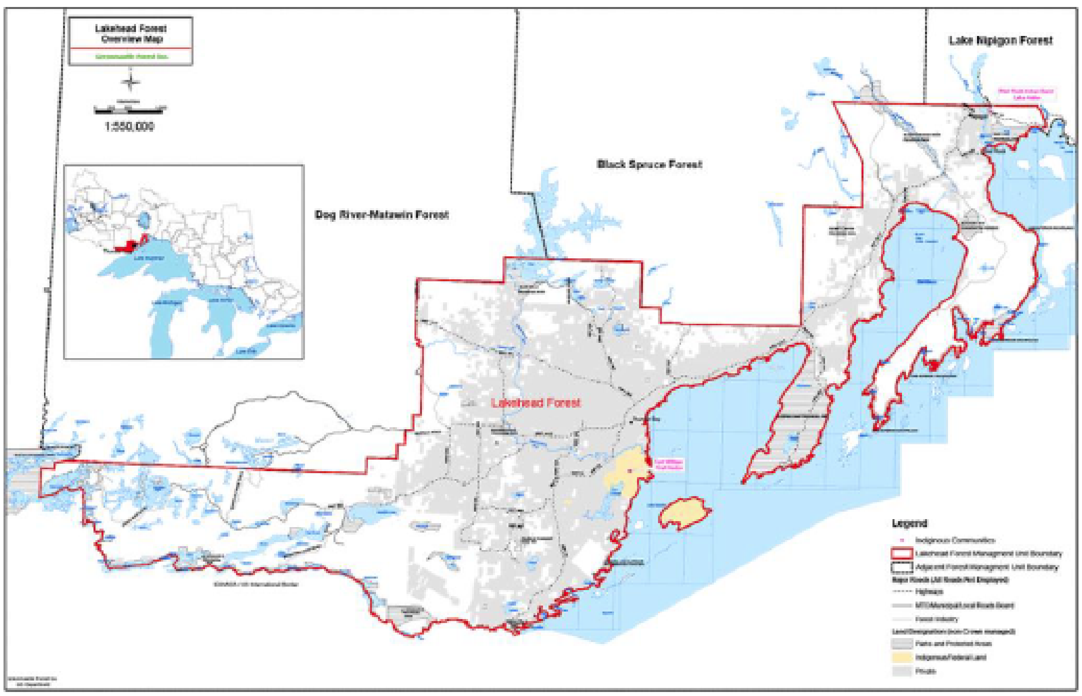

Figure 1: Map of the Lakehead Forest

These results were studied to understand the impacts that each treatment has on Jack Pine, using Mean Annual Increment (MAI) in metres (m) as the unit of measure.

This data was collected throughout the first semester of the 2017-2018 Lakehead University school year. Materials required to conduct this study included:

- Digital caliper
- Meter Stick
- 2.99m plot cord
- Shovel
- Samsung Tablet and Garmin Glo
- GIS shape files of regenerated blocks
- Flagging tape
- Pins
- Black Permanent Marker

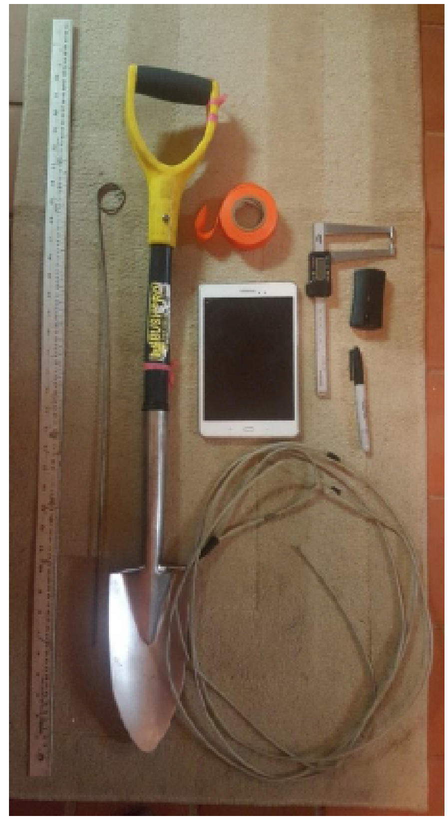

Figure 2: Materials used to collect and mark field data

Six blocks in total were studied, allowing for three repetitions of each of the two treatments. The data collection process involved travelling out to each of these regenerated blocks and choosing 3 points in each block to study. The choosing of these points was based mostly on location, but also the field workers' discretion in order to represent the rest of the block. Once arriving at each location, a shovel was fixed into the ground, which the field worker will use as the center of the plot. A plot cord with a length of 2.99 meters was attached to the shovel, and any trees within this distance of the shovel will be flagged and marked for study.

Figure 3: Map of study areas

After each tree was flagged and marked, each tree was studied for the following characteristics: height (cm), diameter (cm), competition level, and any health defects. This data was entered into a data collection app, and each tree was georeferenced in this app. This study focused on the height characteristic, but other characteristics will be collected for potential future reference. Knowing the age and height of the planted trees, a mean annual increment was determined for each tree. A univariate analysis of variance (ANOVA) was conducted using SPSS Statistics™ to determine the significance site preparation has on planted Jack Pine seedlings. The formula for this ANOVA is as follows:

$$Yij = \mu + Ti + Sj + Sij + \epsilon(ij)k$$

RESULTS

The dependent variables studied and used to produce results were height and root collar diameter. Not used for the results section were defect levels and competition levels of the trees studied, although this data might add insight to the study. For each dependent variable (Height and Root Collar Diameter) both a "Descriptive Statistics" table and a "Tests of Between Subjects Effects" table was produced using SPSS Statistics™ to display the results of the data collected. These two tables compliment each other in that they suggest or confirm whether there is significance between both treatments. Furthermore, treatment one (T1) and treatment two (T2) means for each dependant variable were graphed using Microsoft Excel™ to compare the variability of the data using error bars. These graphs will present a visual representation of the data and will compliment the results by suggesting whether the data is significant or not.

Mean and standard deviation are shown for both treatments (Table 1). In T1, the mean value for height was 25.613 cm of height growth each year. This average was slightly lower than the mean annual increment of height growth in T2 (26.200 cm/yr.). This pattern goes against the pattern that I had hypothesised, which was that T1 sites would have a larger MAI in height than sites from T2. This could possibly be attributed to a number of factors, one of which was that trees sampled in T1 had a higher rate of defect than those in T2. The standard deviation (SD) values in height MAI for T1 and T2 were 2.035 and 3.772, respectively, showing that the results from T1 were more consistent across the sites than that of the results from T2. Although SD for T1 was nearly half of T2, both treatments showed a fairly large SD, which suggests that the data is not very uniform to the mean.

Table 2 (shown below) is the same table as Table 1 but shows root collar diameter as the dependent variable. The mean MAI for T1 was 0.527 cm/yr., which was higher than that of T2, which grew 0.503 cm/yr. This follows the pattern that I was expecting, in that T1 would have a higher MAI of root collar diameter. Seeing that root collar diameter followed the expected pattern, it hints towards the possibility that rate of defect did have an affect on height, and not root collar diameter. The SD for root collar diameter was 0.072 for T1 and 0.097 for T2, showing that data for root collar diameter was not very uniform.

Table 1: Descriptive Statistics. Dependent variable: Height MAI (cm)

Treatment	Mean	Std. Deviation	N
1	25.613	2.035	3
2	26.200	3.772	3
Total	25.907	2.730	6

Table 2: Descriptive Statistics. Dependent variable: Root Collar Diameter (cm)

Treatment	Mean	Std. Deviation	N
1	0.527	0.072	3
2	0.503	0.097	3
Total	0.515	0.078	6

Figure 4 and figure 5 are graphs displaying the means of both treatments for each dependent variable, as well as error bars for each mean. These graphs were produced as preliminary data in order to get an idea of whether or not the difference between treatments was significant or not. To determine potential significance, error bars were added to each mean to show the variability of the data. In each of the two graphs, it is hard to discern whether the error bars overlap between treatments, but the argument could be made that they do overlap. In the case that the error bars do overlap, the significance between the treatments for each dependent variable would be considered insignificant. In the case that the error bars do not overlap, the significance between the treatments for each dependent variable could be either significant or insignificant.

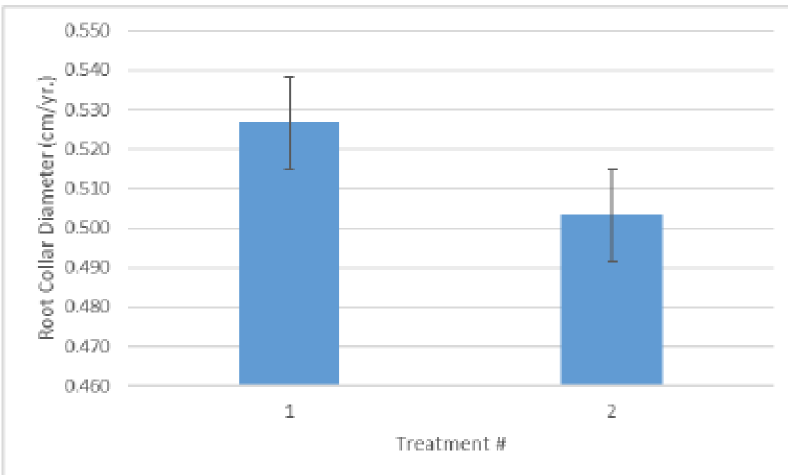

Figure 4: Graphed means of root collar diameter MAI with error bars

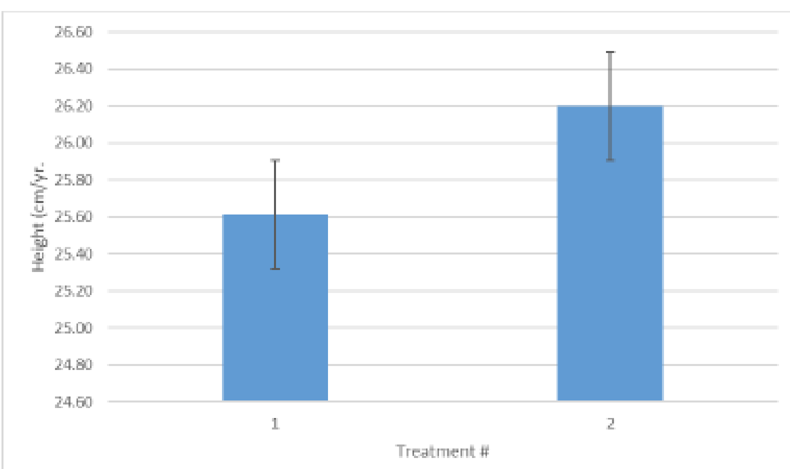

Figure 5: Graphed means of height MAI with error bars

The third type of table produced was the "Tests of between subjects' effects" tables, which ultimately show the significance between the treatments. The confidence level chosen was 95%, making the significance level (P-value) less than or equal to 0.05. The dependent variable, height, is shown below in Table 3 where the significance between T1 and T2 is 0.824. This significance between T1 and T2 of 0.824 is higher than the P value, and so does not meet the significance level required for the data to be significant. Shown on the next page in Table 4, the significance in root collar diameter between treatments is shown to be insignificant as well, as it has a value of 0.755, which is higher than the P value.

Table 3: Tests of between-subjects' effects. Dependent Variable: Height MAI (cm)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.516[a]	1	0.516	0.056	0.824
Intercept	4026.932	1	4026.932	438.422	0.000
Treatment	0.516	1	0.516	0.056	0.824
Error	36.740	4	9.185		
Total	4064.189	6			
Corrected Total	37.257	5			

a. R Squared = .014 (Adjusted R Squared = -.233)

Table 4: Tests of between-subjects effects. Dependent Variable: Root Collar Diameter (cm)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.001[a]	1	0.001	0.111	0.755
Intercept	1.591	1	1.591	217.002	0.000
Treatment	0.001	1	0.001	0.111	0.755
Error	0.029	4	0.007		
Total	1.622	6			
Corrected Total	0.030	5			

a. R Squared = .027 (Adjusted R Squared = -.216)

DISCUSSION

From the results of this study, we can determine that there was no significance between the two treatments; a few limits worth noting can be taken from some of the patterns within the study. This study originally was to compare a number of different site treatments as well as different tree species but unfortunately had to be reduced down to two treatments between one species due to limited study sites and the variability of a number of factors. Within the current study, a number of factors are present that could cause variability in the data; contributing to the significance of the differences between treatments. Some factors that could have affected the results of the study include: the number of growing seasons, site productivity, vegetative competition, time between planting and tending, origin of the planting stock and tree health between the treatments. These factors cannot be proved to have had an effect on the study, although if this study were to be repeated they should be considered more extensively. The factor that possibly had the largest effect on the results of the study was the sample size; the one used in the study was only a minimum sample size required to conduct the univariate ANOVA.

Some of the factors that were expected to have an affect on this study was the overall benefits that site preparation in the form of disc trenching can have on the growth of planted Jack Pine seedlings. Some of the benefits that are a result of altering planting conditions via disc trenching include the alteration of soil conditions and the reduction of competing vegetation.

ALTERATION OF SOIL CONDITIONS

One of the main benefits of disc trenching is that it is able to create a maximum of three available planting spots for the trees, each with their own benefits. As seen in figure 6, the three available spots are in the trench, hinge, and the berm positions. Planting in the trench is applicable on dry sites, planting in the hinge is used for medium sites, and planting in the berm can be used on wet sites. Each of these positions can be chosen at the planter's discretion to provide the best moisture conditions for each tree. Moisture condition is important in seedling establishment because of the small area seedling roots can draw water from in early stages of growth. If the area the tree is planted in is too dry, photosynthesis will be limited, and if the area is too wet, root water uptake will be limited (Von der Gonna, 1992). Other soil properties also affected by disc trenching can be the root zone soil temperature, available oxygen in the soil, and a decrease in frost heaving.

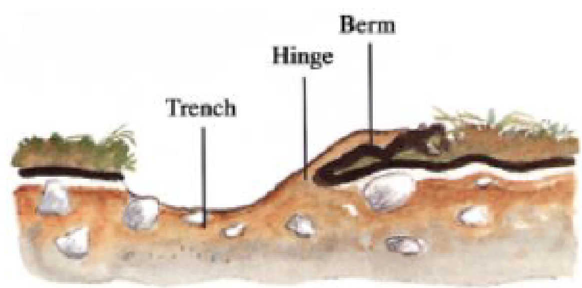

Figure 6: Distinct planting positions induced by disc trenching. Source: FRDA Report 178

Root zone soil (mineral soil) temperature is affected by disc trenching due to the removal of the forest floor (duff layer), which acts as an insulator for the soil below. The exposure of the mineral soil to sunlight during the growing season can increase soil temperatures to optimal growing conditions (between 5 and 25 degrees Celsius) early and late in the season. Temperatures above and below optimal temperatures can reduce the rate of water and nutrient uptake, slowing growth of the seedlings (Mackenzie, 1999).

Available oxygen in the soil partially comes as a result of both soil moisture and soil temperature but is an objective of disc trenching none the less. On some sites, where moisture level is too high, root development can be restricted due to a lack of oxygen. Disc trenching can alter soil to have less density and be aerated to allow increased available oxygen to newly established seedlings (Mackenzie, 1999).

Frost heaving can sometimes be an issue on sites and can result in a large reduction in survival rate of planted seedlings. There are a number of factors that have an affect on whether or not frost heaving occurs, such as snow load, soil type, surrounding vegetation, and planting position. While disc trenching can only control the latter, it might be a specific objective on sites subject to frost heaving. Seedlings that are planted in the trench are more likely to be affected by frost heaving than seedlings planted on the hinge or berm of the scarification. A possible reason for this is the water holding properties of the soil in the trench versus the soil in the hinge or the berm. Moist soils that freeze and thaw more often induce a higher risk of frost heaving than dry soils (Goulet, 2000).

REDUCING LOCAL VEGETATION

Reducing local vegetation is often another objective when forest managers look to regenerate a site and disc trenching can be used to effectively accomplish this objective. Disc trenching disturbs approximately 25-50% of the site when it is applied and effectively removes the top layer of soil, as well as vegetation from these areas. The better part of the scarified area is then vegetation free and would provide adequate sunlight for the growth of planted seedlings. Important factors in effectively reducing local vegetation via trenching include the type of competition on site and the time between planting and site preparation. The type of competition is important because the silvics of some vegetation might benefit from the soil disturbance, such as poplar species. Poplar species regenerate through root suckering, and disturbance to the soil can encourage this type of growth, which would defeat the purpose of reducing competition. Time between planting and disc trenching of the site can also be critical on many sites. The shortest amount of time as possible between treatments is most desirable; as this will pose the least risk of competing vegetation re-establishing themselves in trenches, which would defeat the purpose of reducing competition (Von der Gonna, 1992).

CONCLUSION

The impact that site preparation had on the growth of Jack Pine trees in the Lakehead Forest was shown to have patterns in the study, but overall was insignificant for a number of different reasons. While the main goal was to have the only variable factor between treatments be site preparation, a number of other factors could not be controlled due to the general variability in boreal forest regeneration. Some of these factors include the number of growing seasons, site productivity, vegetative competition, the time between silvicultural treatments, the origin of the planting stock, and tree health. The variability of each of these factors could have affected the results of the study, although it is unknown to what degree. Furthermore, one known factor that has an impact on studies of this sort is sample size, which in this study could have helped discern between the effects of mechanical site preparation and the effects of other variables. If foresters in the boreal forest wish to truly determine whether it is site preparation causing an increase in growth, an increased sample size would be needed to produce significant results.

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APPENDICES

APPENDICES I: STUDY AREAS

III

BLOCK #	LOCATION	SPECIES	STOCK TYPI	TREATMENT	TREATMENT YEAR	TREATMENT	TREATMEN T YEAR	TREATMENT	TREATMENT YEAR	Pre harvest Species Comp.
07-073	Sunset Creek Roa	Pj	309	Mech Site Prep	2011	Plant	2013	Aerial Tending	2014	Sb 40Bf 20Pj 20Bw 10Po 10
07-225	Taylor Road	Pj	309	Mech Site Prep	2012	Plant	2013	Aerial Tending	2014	Bf 40Po 30Bw 10Sb 10Sw 10
07-031	Iron Range Lake	Pj	309	Mech Site Prep	2012	Plant	2013	Aerial Tending	2014	Po 60Pj 20Bw 10Sw 10
07-623	Jaques Road	Pj	309	Plant	2013	Aerial Tending	2014			Pj 50Sb 30Po 10Bw 10
07-487	Twin Mountains r	Pj	309	Plant	2014	Aerial Tending	2016			Pj 80Po 20
07-407	Reta Lake Road	Pj	309	Plant	2014	Aerial Tending	2015			Pj 60Po 20Bw 10Sb 10

APPENDICES II: TREATMENT DATA

Taylor Road: Block 07-225 (5 Years)								
Treatment 1: Site Preparation, Planting, and Tending								
Plot #1		Height (cm)	Diameter (cm)	Defects 0=No 1= Yes	Competition 1 = Low 2 = Medium	Height MAI	Diameter MAI	Comments
Tree #	1	134	3.79	0	1	26.8	0.76	
	2	111	3.68	0	1	22.2	0.74	
	3	138	4.02	0	1	27.6	0.80	
	4	124	3.73	0	1	24.8	0.75	
	5	126	3.81	0	1	25.2	0.76	
	6	123	3.62	0	1	24.6	0.72	
	7	95	1.67	0	1	19	0.33	
Plot #2				0				
Tree #	1	112	3.68	0	1	22.4	0.74	
	2	170	4.68	0	1	34	0.94	
	3	88	1.38	0	1	17.6	0.28	
	4	33	0.60	1	1	6.6	0.12	Browse
	5	118	3.85	0	1	23.6	0.77	
	6	100	3.27	0	1	20	0.65	
	7	149	3.94	0	1	29.8	0.79	
Plot #3								
Tree #	1	91	1.78	0	1	18.2	0.36	
	2	62	1.33	1	1	12.4	0.27	Browse
	3	146	3.77	1	1	29.2	0.75	Top Half Dead
	4	142	2.46	0	1	28.4	0.49	
	5	148	4.01	1	1	29.6	0.80	Browse
	6	134	2.43	0	1	26.8	0.49	
	7	144	3.08	1	1	28.8	0.62	Browse
	8	138	2.70	0	1	27.6	0.54	
	Average	119.36	3.06	0.22	1.00	23.87	0.61	

Sunset Creek Road Block # 07-073 (5 Years)								
Treatment 1: Site Preparation, Planting, and Tending								
Plot #1		Height (cm)	Diameter (cm)	Defects 0=No 1= Yes	Competition 1 = Low 2 = Medium 3 = High	Height MAI	Diameter MAI	Comments
Tree #	1	168	2.87	0	1	33.6	0.57	
	2	100	1.52	0	1	20	0.30	
	3	148	3.08	0	1	29.6	0.62	
	4	98	2.69	1	1	19.6	0.54	Browse
	5	113	2.04	0	1	22.6	0.41	
	6	170	2.99	0	1	34	0.60	
	7	126	2.46	0	1	25.2	0.49	
	8	144	2.59	1	1	28.8	0.52	Top Half Dead
	9	196	3.78	0	1	39.2	0.76	
	10	124	1.88	0	1	24.8	0.38	
Plot #2								
Tree #	1	127	2.72	1	2	25.4	0.54	Top Half Dead
	2	94	2.43	1	2	18.8	0.49	Browse
	3	128	1.98	0	2	25.6	0.40	
	4	186	3.44	0	2	37.2	0.69	
	5	143	2.54	0	2	28.6	0.51	
	6	121	1.62	0	2	24.2	0.32	
	7	84	1.47	0	2	16.8	0.29	
Plot #3								
Tree #	1	141	2.24	0	2	28.2	0.45	
	2	136	1.71	0	2	27.2	0.34	
	3	147	2.22	0	2	29.4	0.44	
	4	134	2.61	1	2	26.8	0.52	Dead Top
	5	211	2.67	0	2	42.2	0.53	
	6	164	1.98	0	2	32.8	0.40	
	Average	139.26	2.41	0.22	1.57	27.85	0.48	

Iron Range Lake. Block # 01-031 (5 Years)								
Treatment #1. Site Preparation, Planting, and Tending								
Plot #1		Height (cm)	Diameter (cm)	Defects 0=No 1= Yes	Competition 1 = Low 2 = Medium 3 = High	Height MAI	Diameter MAI	Comments
Tree #	1	85	1.17	0	3	17	0.234	
	2	100	1.58	0	3	20	0.316	
	3	102	1.69	0	3	20.4	0.338	
	4	133	2.87	0	3	26.6	0.574	
	5	127	2.31	1	3	25.4	0.462	Browse
	6	152	2.55	0	3	30.4	0.51	
	7	167	3.16	0	3	33.4	0.632	
Plot #2								
Tree #	1	161	3.33	0	2	32.2	0.666	
	2	100	1.73	0	2	20	0.346	
	3	104	2.17	0	2	20.8	0.434	
	4	120	2.32	0	2	24	0.464	
	5	131	2.68	0	2	26.2	0.536	
	6	147	2.33	1	2	29.4	0.466	Browse
	7	168	3.40	0	2	33.6	0.68	
Plot #3								
Tree #	1	117	2.61	0	1	23.4	0.522	
	2	125	2.68	0	1	25	0.536	
	3	137	2.84	0	1	27.4	0.568	
	4	109	2.58	1	1	21.8	0.516	Browse
	5	100	2.67	1	1	20	0.534	Browse
	6	116	2.67	0	1	23.2	0.534	
	7	130	2.74	0	1	26	0.548	
	8	132	2.15	0	1	26.4	0.43	
	Average	125.59	2.47	0.18	1.95	25.12	0.49	

Jacques Road. Block # 07-623 (5 Years)								
Treatment 2: Planting and Tending								
Plot #1		Height (cm)	Diameter (cm)	Defects 0=No 1= Yes	Competition 1 = Low 2 = Medium 3 = High	Height MAI	Diameter MAI	Comments
Tree #	1	131	3.22	0	1	26.2	0.644	
	2	87	1.65	0	1	17.4	0.33	
	3	133	3.22	1	1	26.6	0.644	Browse
	4	121	2.58	0	1	24.2	0.516	
	5	137	3.57	1	1	27.4	0.714	Browse
	6	120	3.74	1	1	24	0.748	Browse
	7	110	2.71	0	1	22	0.542	
Plot #2								
Tree #	1	131	3.01	0	1	26.2	0.602	
	2	116	2.28	0	1	23.2	0.456	
	3	153	2.53	0	1	30.6	0.506	
	4	144	2.92	0	1	28.8	0.584	
	5	136	2.61	0	1	27.2	0.522	
	6	115	2.52	0	1	23	0.504	
Plot #3								
Tree #	1	100	1.43	0	1	20	0.286	
	2	104	1.76	0	1	20.8	0.352	
	3	115	2.07	0	1	23	0.414	
	4	110	1.57	0	1	22	0.314	
	5	77	1.40	0	1	15.4	0.28	
	6	64	0.96	0	1	12.8	0.192	
	7	143	2.70	1	1	28.6	0.54	Browse
	8	99	1.58	0	1	19.8	0.316	
	9	112	2.39	0	1	22.4	0.478	
	Average	**116.27**	**2.38**	**0.18**	**1.00**	**23.25**	**0.48**	

Twin Mountains Road. Block # 07-487 (4 Years)									
Treatment 2. Planting and Tending									
Plot #1		Height (cm)	Diameter (cm)	Defects 0=No 1= Yes	Competition 1 = Low 2 = Medium 3 = High	Height MAI	Diameter MAI	Comments
Tree #	1	149	3.22	0	1	37.25	0.81	
	2	122	2.20	0	1	30.5	0.55	
	3	87	2.15	0	1	21.75	0.54	
	4	114	2.19	0	1	28.5	0.55	
	5	136	2.40	0	1	34	0.60	
	6	138	2.4	0	1	34.5	0.60	
	7	127	2.36	0	1	31.75	0.59	
	8	158	2.97	0	1	39.5	0.74	
	9	109	1.97	0	1	27.25	0.49	
	10	129	3.21	0	1	32.25	0.80	
Plot #2								
Tree #	1	120	1.98	0	1	30	0.50	
	2	101	2.63	1	1	25.25	0.66	Browse
	3	118	2.18	0	1	29.5	0.55	
	4	120	2.13	0	1	30	0.53	
	5	128	2.42	0	1	32	0.61	
	6	102	1.67	0	1	25.5	0.42	
	7	127	4.34	1	1	31.75	1.09	Browse
Plot #3								
Tree #	1	124	1.99	0	1	31	0.50	
	2	145	2.80	0	1	36.25	0.70	
	3	123	2.87	0	1	30.75	0.72	
	4	84	1.65	0	1	21	0.41	
	5	116	2.69	0	1	29	0.67	
	6	124	1.95	0	1	31	0.49	
	Average	121.78	2.45	0.09	1.00	30.45	0.61	

X

Reta Lake Road. Block # 07-407 (4 Years)								
Treatment 2. Planting and Tending								
Plot #1		Height (cm)	Diameter (cm)	Defects 0=No 1= Yes	Competition 1 = Low 2 = Medium 3 = High	Height MAI	Diameter MAI	Comments
Tree #	1	78	1.13	0	2	19.5	0.28	
	2	122	1.74	0	2	30.5	0.44	
	3	74	1.46	0	2	18.5	0.37	
	4	72	0.91	0	2	18	0.23	
	5	63	1.14	0	2	15.75	0.29	
	6	81	1.22	0	2	20.25	0.31	
	7	105	2.18	0	2	26.25	0.55	
Plot #2								
Tree #	1	120	2.12	0	2	30	0.53	
	2	103	1.74	0	2	25.75	0.44	
	3	85	1.24	0	2	21.25	0.31	
	4	123	1.67	0	2	30.75	0.42	
	5	122	2.25	0	2	30.5	0.56	
	6	99	1.50	0	2	24.75	0.38	
	7	92	1.64	0	2	23	0.41	
Plot #3								
Tree #	1	105	2.15	0	2	26.25	0.54	
	2	102	1.76	0	2	25.5	0.44	
	3	131	2.01	0	2	32.75	0.50	
	4	108	2.31	0	2	27	0.58	
	5	114	2.46	0	2	28.5	0.62	
	6	86	1.35	0	2	21.5	0.34	
	7	92	1.46	0	2	23	0.37	
	8	114	1.62	0	2	28.5	0.41	
	Average	**99.59**	**1.68**	**0.00**	**2.00**	**24.90**	**0.42**	