The Promoted Growth of Genetically Lodgepole and White Spruce in Western Alberta
Compared to Natural Stocks

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ABSTRACT

Keywords:

Forest regeneration has been an important focus across Alberta and the rest of Canada over recent decades. An industrial company in Alberta known as Canfor have recently began regenerating using a genetic stock where a seed bank has been used from an orchard to create the tallest, strongest and fastest growing trees in the vicinity. Although the trees are genetically improved they are not considered GMO's simply because they have been bred properly and have not endured any unnatural tampering. GMO's are considered genetically modified organisms which have had modification done on them. Orchard trees are improved be breeding the best mother and father within the orchard for cone production and reproducing with these cones. The idea behind this stock is to speed up the reforestation process in post-harvest stands to shorten the harvest rotation and to recreate habitat in a shorter period of time. The results from the findings show a direct comparison between the genetic stock and the natural stock at different age classes from seedling to 5 years of age. The results derived from this experiment are significant to forestry due to its potential for rapid growth which will speed up block regeneration and harvest rotations noticeably in the future.

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ACKNOWLEDMENTS

The author of this thesis would like to acknowledge Christine Quinn who has played big role in creating the foundations for this experiment with this stock along with Rowan Skeavington who aided in obtaining data for Canfor along with managing the stock. We also would like to acknowledge Leslie Proudfoot for her work with IFT and managing the orchard where this stock is grown.

1.0 INTRODUCTION

Genetically improved seedling stocks will improve the reforestation process in forests across Canada. Tree improvement experiments have proceeded in many regions across Canada with similar goals, to allow regeneration of forests to occur faster to aid with environmental factors, forest harvest rotations, limitations of disease spread and to form unanimous tree growth within an even aged stand (Dumroese et al 2015). This paper discusses a genetic stock in Western Alberta that has been designed to speed up the reforestation and strength of tree stocks in black spruce, white Spruce and lodgepole pine. This is done through the breeding lodgepole pine and white spruce that are the tallest, have the strongest fiber, vertical growth and large branches with many needles to improve genetics as much as possible. A similar experiment has occurred in central Ontario and southwestern Quebec where there is a determination that local white spruce populations out preformed stocks from far western Canada and Alaska (Lu and Parker et al 2014). Both stocks are targeted to be strong and reliable with the changing climate and the weather conditions it creates. In western Canada there have been experiments conducted to assess the range in which reforestation strategies would be acceptable and areas where they may not be as acceptable based on climate, ground frost, sunlight availability and soil type (Hajjar and
McGuigan et al 2014). The determination is that strategies such as aerial seeding were best for areas with higher mean annual temperatures and coarse soils to allow seeds to set properly (Hajjar and McGuigan et al 2014). Seedlings dealt with from the improved stock are all manually planted to ensure they have a year of growth in a greenhouse to

display their potential before being placed into soils in natural environments. Tree improvements are becoming a vital part of reforestation programs because of their genetic quality and they're economic value to planted forests (Grubinger et al 2020). In another experiment (Grubinger et al 2020) found that improved stocks of Douglas fir out competed other natural species that were competing for the same resources at the age of 22 years of age through the use of aerial laser scanning. The improved stock in Alberta is attempting display the same results to out compete other species at a young age to form uniform growth within a stand. Improved stocks can also aid in the consumption of more carbon as found by (Cunningham et al 2014). The reasoning for this is due to the fact they are generally stronger, healthier trees than most natural individuals they sequester more carbon than other trees to grow quicker and photosynthesize more than their competition. In British Columbia there are also tree improvement on the interior and coastal regions for a variety of species where they find through field trials which seedlings have strongest heritable traits to help improve seed stocks for environmental aspects (FGC extension note 3). This mimics the improved stock being used in Alberta in the attempt to breed a seedling stock that retains strong heritable features from healthy and tall trees. The genetic stock in Alberta will form a faster growing stock of trees that will speed up the harvest rotation for industrial companies as well as regenerate habitat faster than average stocks.

1.1 Objective

The objective of this study is to determine if the improved stock being utilized in western Canada is able to outcompete normal stocks as well as it's natural competition in stands. Also this study discussed how the stock can display rapid regrowth to shorten the harvest rotation within those same blocks.

1.2 Hypothesis

The genetic stock will display faster regeneration than the wild seed collection stocks and will outcompete natural stocks allowing for a shorter harvest rotation within post-harvest stands.

2.0 LITERATURE REVIEW

2.1. Similar conducted experiments

In many countries where forest management is a high priority groups and corporations are in constant aim for stock improvement to create faster growing healthier wood for industrial business. In one experiment (Ahtikoski et al 2018) discovered that an enhanced breeding program to improve stock reforestation raised production and wood quality significantly across Finland. The stock quality juristically improved land and tree value in juvenile and mature trees especially in the southern portions of Finland where the growing season is longer than portions of northern Finland (Ahtikoski et al 2018). The improvement program had an aim for species such as *P. abies, B. papyrifera, P. banksiana* and *P. tremuloides* which are generally the species the sawmill aim to harvest (Ahtikoski et al 2018). Through the use of stand simulations and physical evidence the improved breeding program created stocks that were able to out compete other species within the area and display considerable rapid growth compared to other species which in turn sped up the harvest rotation for many blocks the sawmill harvests from (Ahtikoski et al 2018). This thesis displays data from an industrial company that has similar targets of creating fast regeneration with high quality tree qualities to speed up harvest rotation and forest regeneration.

In a separate study (Chamberland et al 2020) looked at the cost benefits of using genetically improved *P. glauca* stocks in Quebec. The focus is looking at genetic gain to shorten the breeding cycle while also improving gains to growth speed thus lowering general costs for stock management and stand management due to the juristically improved stock (Chamberland et al 2020). To capture the genetic gain in these seedlings the use of somatic embryogenesis was used which is known to be the best way to obtain the best genes through vegetation propagation (Chamberland et al 2020; Bonga et al 2016; Klimaszewska et al 2007). The determination is that *P. glauca* trees display significant growth rates in the juvenile stages between years 20 and 45 where the creation of merchantable wood was at its peak and was resilient and able to outcompete at younger ages with other species (Chamberland et al 2020). The cost effect was significantly lower once the stand reached the juvenile stages and free to grow status and range from $200-$2000 less per hectare due to less stand management practices needed to keep it in a healthy functional state (Chamberland et al 2020). This same information can also likely aid for the data obtained in this thesis due to the use of similar methods used in the enhanced stock and the use of same species of *P. glauca* in western Alberta.

(Haapanen et al 2016) experimented on *P. sylvestris* in southern Finland to determine the projected gains and yield of genetically improved tree stocks of that species in a 14-15 year period. This experiment was ran through a seed orchard to display the realized gains of the seed lot over the course of the 15 year period (Haapanen et al 2016). The overall projection of gain within the Scots pine at the 15-year mark was 40% greater than the average *P. sylvestris* stock regarding the diameter and tree height with genetic versatility also being higher than the generic stock (Haapanen et al 2016). There is an indisputable display of genetic gain within the improved stocks stems in a wide range of features including tree height, DBH, carbon intake and fibre quality meaning a majority of the stems created within this stock are significantly stronger than a majority of the average stems within a normal breed of *P. sylvestris* (Haapanen et al 2016). This experiment is significant due to the fact that the seed bank used in improved stock in Alberta was also created and used through a seed orchard and maintained in similar ways to form similar results such as this experiment in Finland.

2.2. Government involvement

The USDA Department of Agriculture (1992) have been aiming to form continuous improvements to reforestation and genetics within tree seedlings to create faster growing stems across the United States (USDA Department of Agriculture 1992). The application of seed zones across several different states to recommend different seedlings to areas with varying soil quality and nutrient levels (USDA Department of Agriculture 1992). The management of seed orchards in southern and western states have been improving to gain genetically quality and to prune or remove less desired species to create larger amounts of species with ideal genetic strengths such as rapid growth (USDA Department of Agriculture 1992). This has become the national expectation for managing seed stocks for industrial reforestation in states in the southeastern and pacific west regions of the United States to aid in maintaining forests

(USDA Department of Agriculture 1992). Many of these practices and expectations are similar to Alberta's forest management and seed zone management which have shown great results over recent decades.

The Ministry of Forests and Range (2000) in B.C have made vital changes over decades in the 1990's to create strong modern forests that lie across the B.C interior and coast today. Western hemlock (*T. heterophylla*) are a target species for improvement of genetic gain and have become a productive species through the process of selection breeding and through testing of quality of several stems per seed stock (Ministry of Forest and Range 2000). The two most improved stocks between the early 90's and into the 2000's are lodgepole pine (*P. contorta*) and interior spruce *Picea* due to the fact that they carry a high economical value due to their ideal fiber qualities (Ministry of Forest and Range 2000). Tree improvements have been done based on soil quality in nearby regions due to the varying forest types and change in landscape between the interior and coastal portions (Ministry of Forest and Range 2000). Doglas fir (*Pseudotsuga menziessi*) is also an improved and managed species on coastal and interior B.C which has displayed it's highest genetic gain in the early 2000's based on the projected seeding regions in the year 2000 (Ministry of Forest and Range 2000). This information is important because across Canada seed zones have become a huge role player in what species and seed type are planted in different areas and what kind of genetic improvements can be made to those seed types.

2.3. Soil type importance for improved stocks

Antisari et al (2015) found the importance of soil quality and carbon availability after reforestation to be a large role player in Douglas-fir (*P. menziessi*) stocks as they replenish stands after a harvest. The mineral soil in this study where Douglas-fir (*P. menziessi*) stands rejuvenated continued to become more and more nutrient abundant as they aged on due to the dispersal of microbial activity (Antisari et al 2015). At high altitudes Douglas-fir (*P. menziessi*) became very adaptive and was able to outcompete other species and grow to similar heights to other fir species at lower altitudes (Antisari et al 2015). It is also determined that soil depth also played large factors in growing stability due to the fact that soil depths change constantly with changing landscapes at higher altitude (Antisari et al 2015). This information is important to keep in mind because the genetically improved stock in western Canada is also planted in varying altitudes and is able to outcompete species via growth from lower foothills to the Canadian Rockies.

Kildisheva et al (2017) targeted stone pine *P. pinea* in Lebanon to improve the stock to be able to compete with the semi arid conditions and ecologically diverse regions to create a stronger species to unanimously reforest areas. With the harsh conditions in western Asia many tree stocks have a hard time gaining consistent growth hence why this study was done on *P. pinea* to hopefully create and maintain a *pinus* forest in arid conditions (Kildisheva et al 2017). With continuous monitoring they are able to determine over time the improved *P.* pinea stock is able to withstand the Lebanese conditions with consistent growth and high mortality rates against other local species (Kildisheva et al 2017). The stock created was once again mixed with other *P. pinea* species with high genetic quality and grown in harsh conditions so that each individual is able to withstand extreme dry conditions (Kildesheva et al 2017). The growth of the *P. pinea* was slow however it was consistent and showed minimal effects from low water availability and dry conditions in deep coarse soil (Kildesheva et al 2017). The genetically improved stock in Alberta's strong growing genes allow them to grow in areas are considerably dryer than ideal locations which is why this article proves its importance that these stock improvements allow for seedlings to grow and reproduce in a variety of different conditions and soil types.

2.4. Economic improvement from genetic stocks

In another experiment Cullingham et al (2013) looked at the genetic structure of lodgepole *P. banksiana* and jack pine *P. contorta* to see what economical values they hold and what allows them to grow in the areas they do but not have allow extensive mixture across the continent. Through extensive internal views of both species it is determined that the internal fiber is what form the high economic value for both species and no matter the speed of growth the fiber value stays relatively the same due to the genetic makeup both species (Cullingham et al 2013). With this in mind the experiment viewed the relative growth rates of both species in different regions of Canada and determined that the soil type depth played a larger role in the commencement and stoppage of growth as seasons change due to the available water throughout the overall root stems (Cullingham et al 2013). This information is important due to the discussion of wood fiber and how it may be effected if the individuals display more rapid growth. The answer to that is no due to their genetic makeup they will still have economically sound fiber that are not deterred due to growing speed in vertical or DBH growth.

Fleming et al (2001) studied the effects of direct seeding for seedlings and how they are able to adapt to environmental factors and establish themselves while beating out the competition. At young ages the seedling are prone to display significant damage to future growing aspects and strength of the stem when exposed to environmental aspects such as extreme moisture exposure, extreme heat or cruel winters which can damage the rooting system (Fleming et al 2001). The success of most seedling stocks is based on the top soil it is planted in and expand rooting systems to grasp nutrients within the soil and have constant water available while also significant sunlight availability (Fleming et al 2001). This information is significant because with a stock that can grow quicker than normal natural seedlings they will also be able to expand rooting systems faster especially in ideal soil systems. The shorter period of time the seeding's are in the young and juvenile stages the less likelihood they will be effected by environmental causes.

Wagner et al (2001) discussed vegetation management and the practices endured to create healthy ecosystems which mimic that of previous forest stands. There is an abundance of information regarding the environmental conditions and how they have an effect on vegetation regeneration along with soil type (Wagner et al 2001). When areas are harvested there is a significant need to begin managing the area quickly as many undesirable species may take over quickly disallowing other species to regenerate properly or with much density (Wagner et al 2001). Many practices are done to manage vegetation densities in different forests to allow them to be replanted so that the species composition shows similar values to what it was before harvested (Wagner et al 2001). Practices such as pruning, thinning and herbicides are used across many different countries and provinces/states to deter vegetation or allow other types of vegetation to regenerate (Wagner et al 2001). This information is important due to its necessary help for regenerating forest stands and how species compete for resources depending on the amount of competition occurring within stands. With a stock that displays rapid growth the amount of time seedlings will be effected by low lying vegetation is shorter than other stocks which also lower costs on management practices to their lesser need to be used.

3.0 MATERIALS AND MERTHODS

3.1 Locations

A variety of different sites were used to collect data for this thesis including tree orchards, planted cut blocks on industrial land and greenhouses where seedlings are grown from. In one cut block there were two (2) 1.6-1.9 hectare sections cut out and planted with the genetically improved stock while the rest of the block was planted with the natural stock. After randomly choosing ten stems in the 1.6 hectare genetic plots and ten stems in the wild seed collection portion of the block a measurement was taken on each of the ten stems and recorded to determine any sort of difference in size. The stand chosen for this experiment was planted five years prior to the data being collected with the seedlings being a total of six years old from the greenhouse.

The location where this study has taken place is in Northwestern Alberta just south of Grande Prairie. The 1 hectare plots with genetic stock inside are displayed in figure 1. This cut block is located in the foothill region of Alberta toward the southern portion of Canfor Grande Prairie’s FMA (forest management agreement) near Grande Cache. The stand has a significant slope on the south side and has a relatively high amount if sunlight available throughout a day cycle. The stand mainly was replanted with lodgepole pine (*P. contorta*) with a small amount of natural regeneration of hardwoods allowed to grow.

Figure 1. Google maps image displaying the cut block where the 1 hectare test locations for the genetic stock lye. The coordinates for this location are; 54 21’46”N 117 54’34”W (Google Maps 2021).

In a secondary location a cut block which is considerably smaller than the one shown in figure 1 was broken into a smaller chunk to run a similar test with a slightly larger area in a region closer to the mountainous region of the forest. The image displayed in figure 2 is a cut block planted in 2021 with genetic and half wild stock. The cut blocks chosen for these experiments vary in location and accessibility where varying interaction with nature and other environmental and human made factors which are planned to determine the strength of the improved stock.

Figure 2 Displays the cut block where a small portion of the area was dispersed to use for genetic stock growth and measure it up to the natural stock in the rest of the block (Google Maps 2021).

The next figure displays the block under a colour scheme which shows where the block was separated between the genetic stock and the natural stock. The entire block is 12 ha in size with a maximum elevation of 1180 meters however the area planted with genetically improved stock is only 1.7 ha. The roadway running alongside the block is well maintained and heavily used however is strategically placed so that the differentiation between genetic and natural stock will be easily noticed roadside.

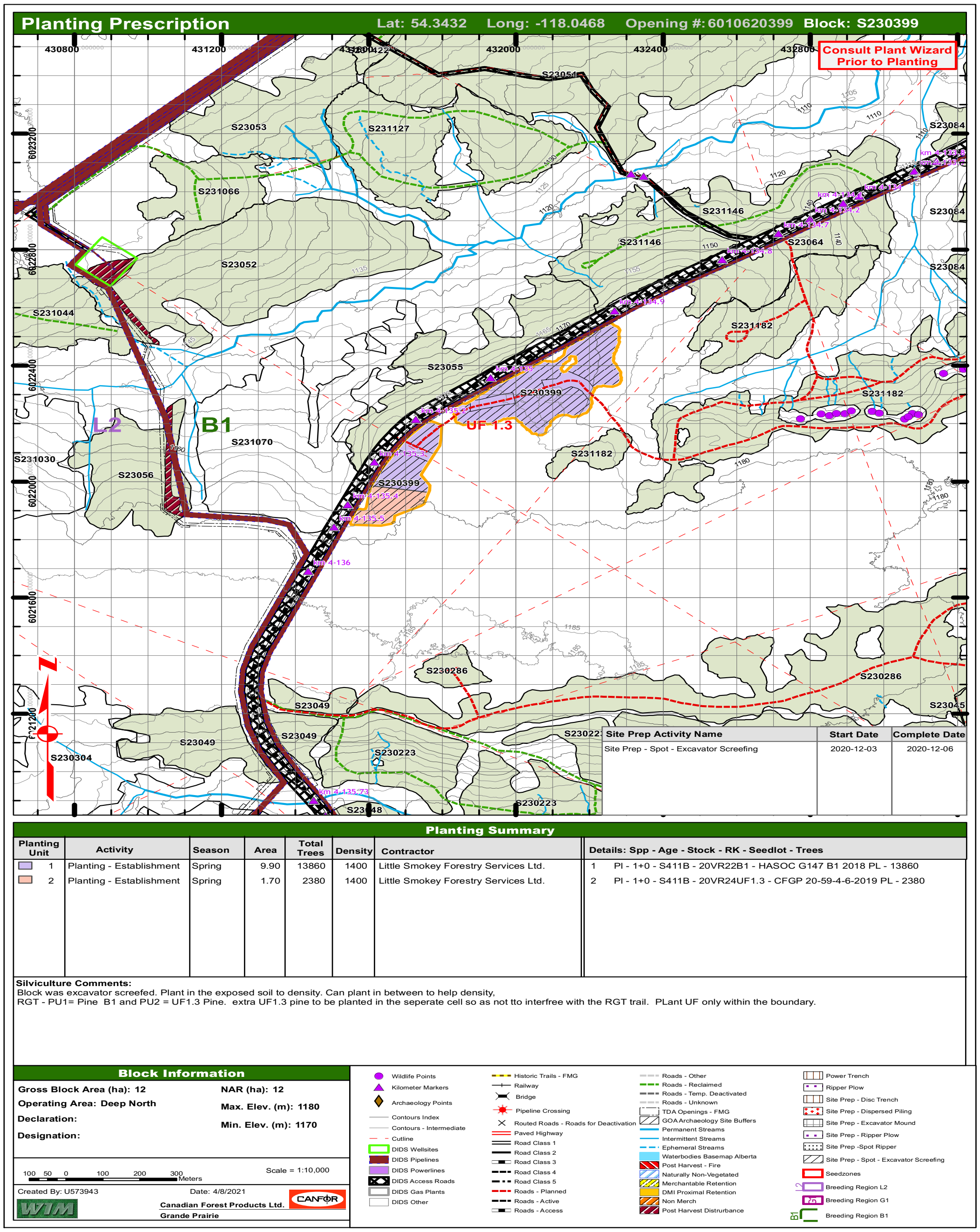


Figure 3 Displays the block map which the RGT (realized gain trail) was conducted along with the gross area and declaration (Skeavington 2021).

3.2 Data Collection

The stems used within the RGT were all measured at the 1 year old stage regarding height, DBH if recordable, any noticeable lean, stem health and each stem was numbered (Skeavington 2021). All RGT data was recorded on an IPad then eventually upload into an excel spreadsheet which is available in the results section. If any noticeable defect on the seedling appeared it is recorded and determined whether or not the seedling was healthy enough to be planted and used as an RGT (Skeavington 2021). Majority of any defects consisted of broken tops or a slight lean which regenerate or can be rectified over time allowing the seedlings to be planted and still able to function (Skeavington 2021). Some natural regeneration within the block was needed therefor also recorded within the excel spreadsheet but not part of the RGT trail. Likewise, the wild seed stock was also recorded in order to keep documentation of both stocks over the course of time, however the genetically improved stock is given priority in the data being that they are the focus of the experiment (Skeavington 2021).

RESULTS

4.1 Age to Height Comparisons

The in-field measurements were calculated in two different cut-blocks with RGT's based in each block. As noticed in Figure 4, the average growth heights for seedlings after 1 year of growth is taller for improved stocks (18.8 cm) compared to the average natural stocks heights (15.3 cm). In both cut-blocks the main species planted was lodgepole pine (*P. contorta*). Blocks that had data taken from them had planting checks conducted well before the data was written.

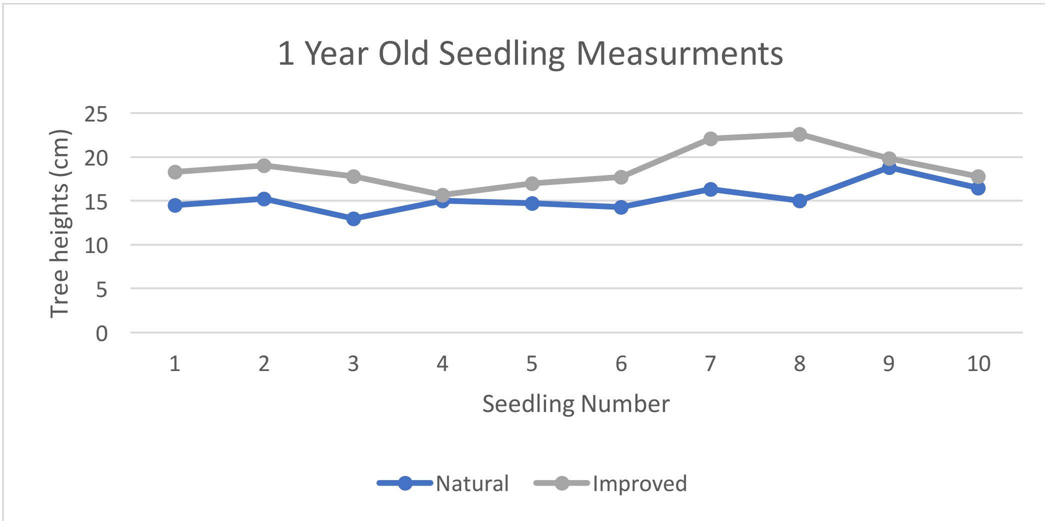


Figure 4. A line graph displaying the seedling stem heights of 10 different lodgepole pine natural and improved seedlings after 1 year of growth.

The table recording these values in a numerical form is on display in Table 1. It can be noted that although some wild seed collection record similar heights to that of the improved stock the overall heights for both show significant separation.

Table 1. The seedlings randomly selected for both the natural and improved stocks recorded in centimeters.

1 Year Old Seedling Measurements (cm)	
Natural	Improved
14.5	18.3
15.2	19.0
13.0	17.8
15.0	15.7
14.7	17.0
14.3	17.7
16.3	22.1
15.0	22.6
18.8	19.8
16.5	17.8

In a separate block 2 separate 1 hectare RGT's were implemented where improved *P. contorta,* were planted and have grown for 5 years. It is noticed in Figure 5 that the improved seedlings continues to show rapid growth more so than wild seed stocks even after a 5-year period. The rest of the block was planted with wild lodgepole pine also 5 years previous to when this data was collected.

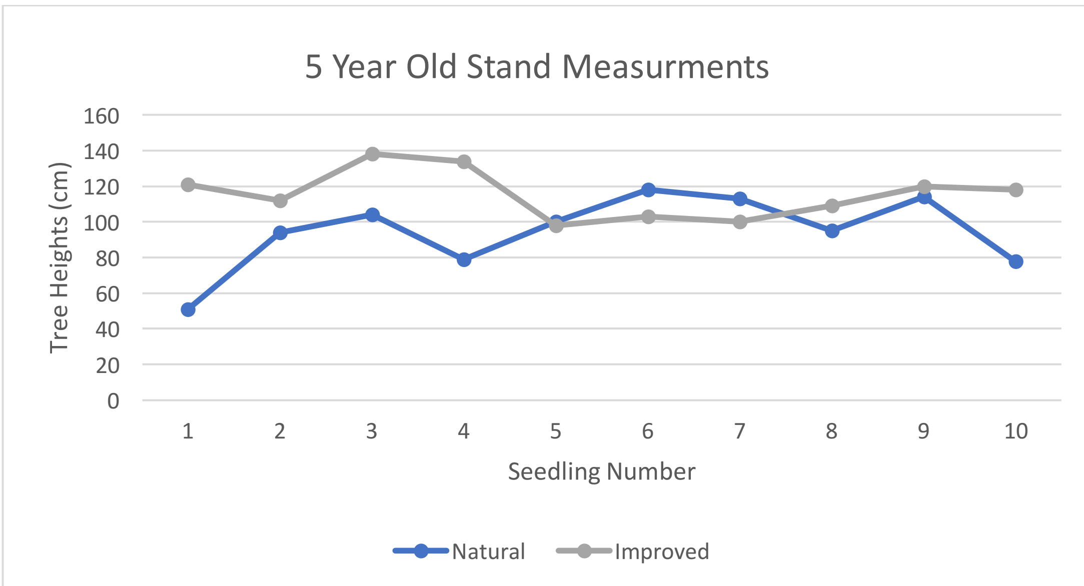


Figure 5. A line graph showing the recorded lodgepole tree heights in cm after a 5-year period of growth in a block with RGT's present.

These values are once again recorded in a table and is seen in Table 2 the numerical values of each individual recorded in the natural and improved stocks separated in the block.

Table 2. The randomly selected seedlings in the 5-year old stocks of natural and improved seedlings.

5-Year Old Stand Measurements (cm)	
Natural	Improved
51	121
94	112
104	138
79	134
100	98
118	103
113	100
95	109
114	120
78	118

4.2 Seedling Health on Improved and Regular Stocks

Data taken on seedling health after a full year of growth in their respected cut blocks in both lodgepole pine and white spruce species. Figure 6 displays data on the healthy versus the defect individuals in a large sample size of the regular stock.

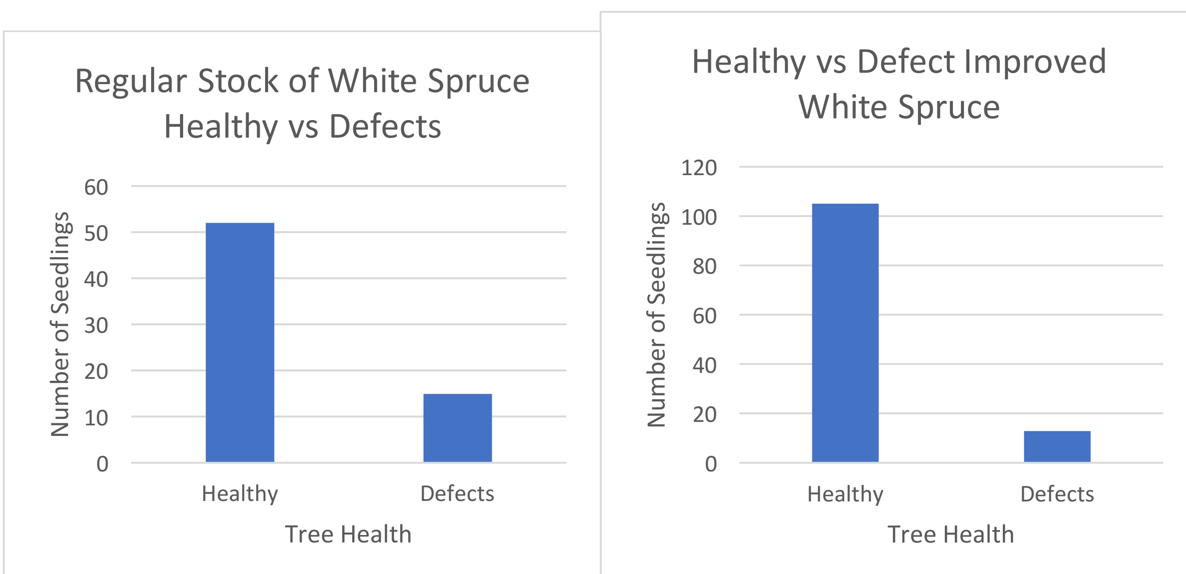
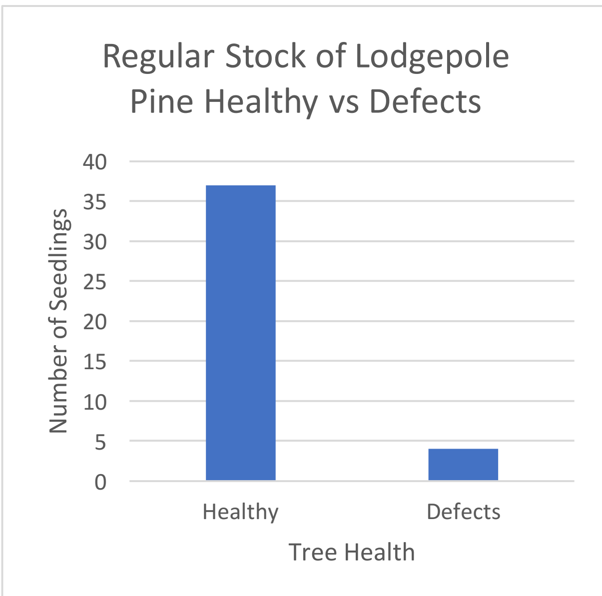


Figure 6. A large randomly selected sample size of individuals who display healthy growth and growth that has been disturbed or a visible disease between both improved and natural stocks (Bertram 2018).

The same type of data was recorded for lodepole pine in figure 7 with values from a regular and improved stock in a large sample size. For this species, the regular stock appeared to not display significant amounts of defects unlike the regular white spruce stock.



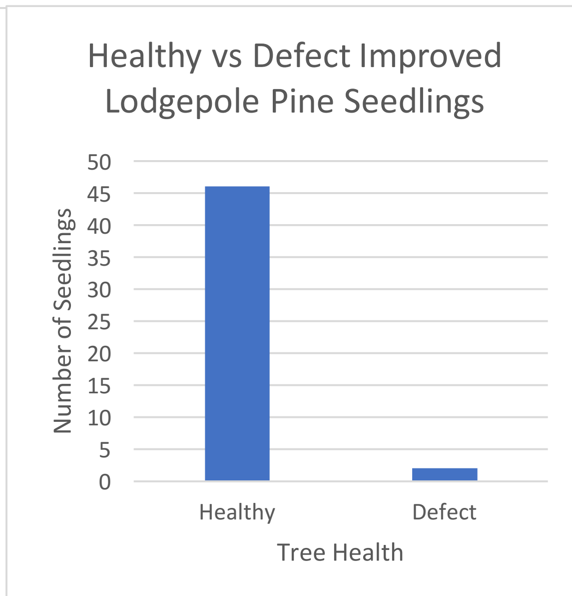


Figure 7. The regular and improved stock of lodgepole pine in a large cut block recording the healthy to defected seedlings (Bertram 2018).

As we can see there appears to be some more seedlings displaying defects in the natural stock however, it is not as noticeable as the white spruce values.

4.3 Statistical Analysis

From the data measured above there appears to be a consistent extension of growth as the average height for the improved stock after 1-year of growth was 18.8 cm whereas the natural stock displayed heights of 15.3 cm. Notably, after 5-years of growth the average height recorded for improved stock within the sample was 115.5 cm compared to 94.6 cm in the natural stock. After a 5-year period the height distance between the improved and natural stock is 6 times larger than it was after only a year of growth.

We are able to compare and contrast the amount of healthy and defected trees between both the natural and improved white spruce and lodgepole pine.

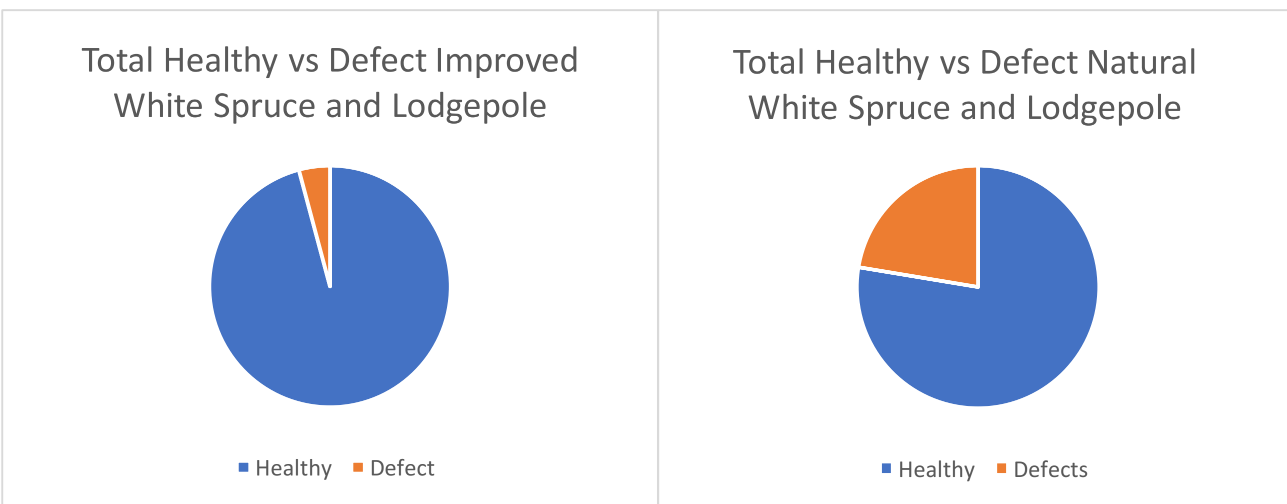


Figure 8. Pie graphs displaying the total amount of healthy and defected trees on all improved individuals measured along with all natural individuals measured.

We are able to determine that overall more individuals were deemed healthy in the improved stock than the natural stock by a very noticeable amount.

DISCUSSION

5.1. Height Comparisons

As seen the results above, in the first year of growth there is a noticeable size differentiation between the improved seedlings and the natural seedlings on nearly every individual measured. In figure 4, the mean height for natural seedlings after one full year of growth is 15.33cm whereas the improved stocks average 18.78cm. Although this is only after a single year of growth we are able to infer that continuous growth with these statistical differences will become more and more noticeable after more time has passed.

In figure 5, you once again will notice a large differentiation between improved and natural seed stocks after a 5-year period. With a mean height of 94.6cm for natural seedlings and a mean of 115.3cm for improved stock it is evident that there is a continuation of significant growth for the genetically improved stocks compared to the natural stocks. This rapid growth will benefit economic value in the future as it will create larger log volume as harvests are being conducted. A prime example of these benefits is shown by Ahtikoski et al (2020) where they measured the economic performance of genetically improved stocks in Finland regarding log volume and fiber strength. It is determined that the overall log volume increased using the improved stock while still maintaining the same strength in fibers that are contained in northern hardwoods and softwoods. The lodgepole pine measured in booth stands were all bred in harsh northern climates yet are still displaying significantly faster growth when improved compared to any natural pine. Even though northern trees vary in growing speed and overall height they still build strong fibers in order to counteract the harsh winter to avoid interior damage and potentially put the individual at risk (Ahtikoski et al 2020, Ostlund et al 2013, Welling and Palva et al 2006).

Overall genetically improved pine species in particular lodgepole pine display the quickest growth rates compared to spruce or other species (Skeavington 2020). The characteristics of these individuals is on display being that the RGT was laid out on dry soil with lots of potential root extension and the ability for a deep tap root to grow. The RGT's are small enough so that both natural and improved seedlings have similar soil types and the same nutrients available to them so that the extent of growth in the improved stocks is noticeable compared to the natural stock. The sites selection of RGT had similar topography and ecosite meaning that factors such as slope and soils are not a potential effect in the experiment. In year 1 the improved stock had an average height that is 3cm taller than the natural stock. After a 5 year period the improved stock have a 20cm height advantage over the natural stock. With this in mind we can project that there will be a noticeable size difference between the genetic stock and natural stock once they reach the juvenile stage.

5.2 Seedling Health on Improved and Wild Seed Stock

After a year a full year rotation of growth it can be seen that the wild seed stock of white spruce display significantly higher number defect trees compared to the improved stock. Majority of the defects discovered were needle shortages, wilting or colour change throughout the seedling. In order for white spruce to display ideal growth when put in the natural environment it must first experience compact growth in containerised products to ensure root compaction is in a good state when planted in a natural setting (Carles et al 2011, Himanen and Nygren et al 2013, Weixing et al 2007, Stowe et al 2001). The seedlings measured in this experiment are grown in these same containers for a full year before being planted therefor they both begin with similar root compaction once they are planted in their natural settings. This means that neither the improved or normal stock have a visible advantage or disadvantage from the nursery to the blocks which they are planted.

The pine species displayed similar data however, the amount of healthy to defect seedlings is considerably closer between improved and wild seed collection compared to the white spruce. Generally, lodgepole pine will display defects regarding their vertical growth such as forking or significant knots (Barbeito et al 2021). Majority of the defects found on these seedlings were knots odd branching near the base of the stem along with small amount of gall rust found on individuals near the edge of the block. These pine species had similar root compaction in containers within nurseries that are displayed with white spruce and were planted in ideal soil types for lodgepole pine such as deep sand flats with lots of root reaching potential. It's worth noting that seedlings recorded at all sites had been surveyed after a tree plant and ensured that a majority of all seedlings had been planted properly with the best potential for fast growth. With the correct spacing for pine species after being planted it is known that fewer growing defects occur as found by Lizeniewicz et al (2012). In southern Sweden a managed stand of lodgepole pine was given a prescription of 3 meter spacing when initially planted and monitored over a 23 year period. After 23-years it was determined that there was minimal occurrence of tree deformity due to abundant space for tap roots and significant vertical and horizontal growth. Although the seedlings recorded in this experiment did not have

3 meters spacing there was still large gaps between each individual giving the potential for similar outcomes for these pine seedlings.

All species recorded as genetically improved were young (only a year or two old) due to the fact that available blocks were within 6 years of age even though tree improvement have been a record for Canfor since 1995. Although these are considered young and immature individuals we are still able to forecast growth projections based on the data that has been collected to date. This display of extensive growth over natural stocks can also forecast larger volumes of harvestable potential once these species reach a mature age which may benefit industrial corporations significantly. Similar results have been noticed in sawmills in Finland with similar species as per Ahtikoski et al (2018) where sawmills have had realized gains in volume after long periods of growth for genetically improved lodgepole pine and white spruce. These gains have come to fruition through similar experimentations conducted of which the forecasted growth estimates appeared to be accurate.

Realized increase in growth may raise skepticism of how strong the fibers of rapidly growing trees may be however, a secondary experiment conducted by Ahtikoski et al (2020) measured the strength properties of these genetically improved species of which it was determined that these stocks still displayed strength properties which can be used for joints and support beams produced from sawmills. The wintering periods still allowed for interior fibers to strengthen similar to that natural species but the return growth in the spring occurred quicker and earlier than a majority of the natural species allowing for rapid growth. The sites of these experiments had well drained soils, significant sunlight availability, nutrient availability along with similar amounts of water available meaning all individuals genetic or not had ideal growing sites. Sites such as these are beneficial for a variety of species including many deciduous species such as poplar which generally display rapid growth within nutrient rich sites without improvement to genetics (Balantinecz and Kretschmann 2001). It is safe to determine that the strength properties of the genetic stock within this experiment will be the same as natural stocks with the strong fibers of northern tree species.

5.3 Species Comparison

Although there are signs of improvement in all species utilized in this experiment, the most notable height difference is displayed in lodgepole pine. At ages, younger than 1 year old there are noticeable height differences between white and black spruce however these differences do not change over time whereas lodgepole pine continue to expand on their growth over natural seedlings over time. On that note, improved white spruce appeared to have fewer overall defects compared to natural white spruce at a young age of which lodgepole pine did not display these features. There is no significant amount of data for white spruce in juvenile or older ages that are improved due to the fact that these improved species have only been regenerating for 6 years within these designated cut blocks. Black spruce individuals displayed significant growth over natural species after 1 year of growth however these individuals did not maintain continuous extended growth as they maintained their height gap over other species and natural stocks. There was also no significant difference between amounts of defects on improved black spruce and natural stocks.

6.0 CONCLUSION

To conclude the data compiled determines that genetically improved seedling stocks will improve the reforestation process in western Canada. Although there is only 6 years of growth data compiled, there is a noticeable trend of rapid growth occurring in a variety of different species. Considering that similar experiments have recently been conducted in Finland by Ahtikoski et al (2018) with similar results in similar species groups we can concur that breeding seedlings with strong characteristics such as height, significant foliage and minimal defects is a good way of reforming strong seed stocks which will display rapid growth.

These results are best displayed when seedlings are planted in ideal locations such as dry sandy area with well drained soils so that they may grow deep tap roots. Along with this ensuring proper spacing between each seedling is also key for ensuring that rapid growth will be on display along with other ideal features. With growth sped up in many cut-blocks we can interpolate that harvest rotations will also be sped up considering that the stock will reach maturity faster than other natural stocks.

Ensuring cut-blocks to regenerate quicker is beneficial for environmental purposes such as habitat rehabilitation meaning that wildlife will be able to repopulate or recolonize areas harvested quicker than if they were regenerated with natural stocks. This lowers the length of time which a cut-block appears non-forested which is likely to please the general population along with government officials striving to aid environmental factors. Other experiments must be conducted on these improved stocks to determine if they display this extensive growth in other species across North America and if they are able to consume larger amounts of carbon in order to maintain this additive growth over extensive amounts of time. These stock improvements can likely aid in many different government, commercial and industrial parties for economic and environmental purposes.

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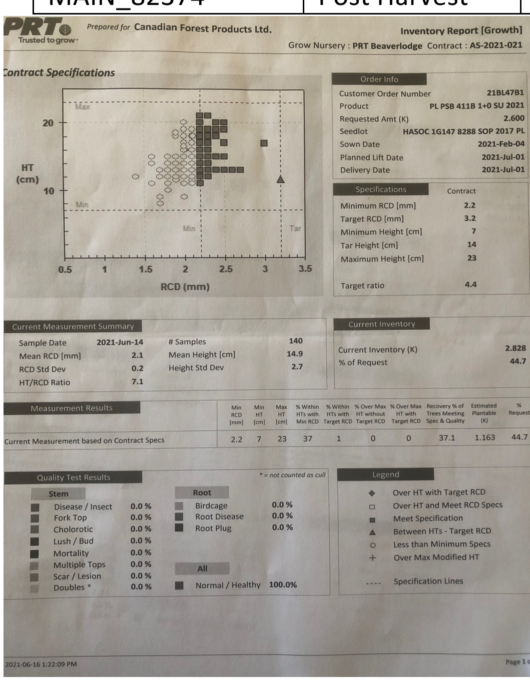
8.0 APPENDICES

Stand Number	Stand Type	Stand Origin	Topographic Position	Slope	Aspect	Elevation
MAIN_83535	1st Rotation Post Harvest	Planted	Middle slope	32	NW	1087
MAIN_83536	1st Rotation Post Harvest	Planted	Middle slope	28	NW	1086
MAIN_77890	1st Rotation Post Harvest	Planted	Flat	3	NW	863
MAIN_78129	1st Rotation Post Harvest	Planted	Flat	2	N	874
MAIN_108929	1st Rotation Post Harvest	Planted	Middle slope	5	NW	1816
MAIN_77734	1st Rotation Post Harvest	Planted	Lower slope	6	N	1427
MAIN_77411	1st Rotation Post Harvest	Planted	Lower slope	9	NE	1734
MAIN_108930	1st Rotation Post Harvest	Planted	Flat	4	S	1284
MAIN_108909	1st Rotation Post Harvest	Planted	Flat	4	S	1006
MAIN_76875	1st Rotation Post Harvest	Planted	Flat	4	SW	923
MAIN_82373	1st Rotation Post Harvest	Planted	Upper slope	3	SE	1129
MAIN_82374	1st Rotation Post Harvest	Planted	Upper slope	8	SE	1272



PRT Trusted to grow Prepared for Canadian Forest Products Ltd.

Inventory Report [Growth]

Grow Nursery : PRT Beaverlodge Contract : AS-2021-021

Contract Specifications

Order Info

Customer Order Number	21BL47B1
Product	PL PSB 411B 1+0 SU 2021
Requested Amt (K)	2.600
Seedlot	HASOC 1G147 8288 SOP 2017 PL
Sown Date	2021-Feb-04
Planned Lift Date	2021-Jul-01
Delivery Date	2021-Jul-01

Specifications	Contract
Minimum RCD [mm]	2.2
Target RCD [mm]	3.2
Minimum Height [cm]	7
Tar Height [cm]	14
Maximum Height [cm]	23
Target ratio	4.4

Current Measurement Summary

Sample Date	2021-Jun-14	# Samples	140
Mean RCD [mm]	2.1	Mean Height [cm]	14.9
RCD Std Dev	0.2	Height Std Dev	2.7
HT/RCD Ratio	7.1		

Current Inventory

Current Inventory (K)	2.828
% of Request	44.7

Measurement Results	Min RCD [mm]	Min HT [cm]	Max HT [cm]	% Within HTs with Min RCD	% Within HTs with Target RCD	% Over Max HT without Target RCD	% Over Max HT with Target RCD	Recovery % of Trees Meeting Spec & Quality	Estimated Plantable (K)	% Request
Current Measurement based on Contract Specs	2.2	7	23	37	1	0	0	37.1	1.163	44.7

Quality Test Results * = not counted as cull

Stem		Root	
Disease / Insect	0.0 %	Birdcage	0.0 %
Fork Top	0.0 %	Root Disease	0.0 %
Cholorotic	0.0 %	Root Plug	0.0 %
Lush / Bud	0.0 %		
Mortality	0.0 %	**All**	
Multiple Tops	0.0 %	Normal / Healthy	100.0%
Scar / Lesion	0.0 %		
Doubles *	0.0 %		

Legend

◆ Over HT with Target RCD
□ Over HT and Meet RCD Specs
■ Meet Specification
▲ Between HTs - Target RCD
○ Less than Minimum Specs
+ Over Max Modified HT
---- Specification Lines

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Origin	Species	DBH	DBH Height	Height	Lean	Azimuth To Height	RC	Root Collar Height	Subplot
Planted Genetically Improved	PL		1.3	0.09			0.4	0	Regen #1
Planted Genetically Improved	PL		1.3	0.17			0.3	0	Main #1
Planted Genetically Improved	PL		1.3	0.14			0.5	0	Main #1
Planted Genetically Improved	PL		1.3	0.16			0.4	0	Main #1
Planted Genetically Improved	PL		1.3	0.1			0.4	0	Regen #1
Planted Genetically Improved	PL		1.3	0.15			0.4	0	Main #1
Planted Genetically Improved	PL		1.3	0.07			0.4	0	Main #1
Planted Genetically Improved	PL		1.3	0.06			0.3	0	Main #1
Planted Genetically Improved	PL		1.3	0.13			0.4	0	Main #1
Planted Genetically Improved	PL		1.3	0.11			0.3	0	Regen #1
Planted Genetically Improved	PL		1.3	0.14			0.5	0	Regen #1
Planted Genetically Improved	PL		1.3	0.09			0.4	0	Main #1
Planted Genetically Improved	PL		1.3	0.05			0.4	0	Main #1
Planted Genetically Improved	PL		1.3	0.04			0.3	0	Main #1
Planted Genetically Improved	PL		1.3	0.11			0.3	0	Main #1
Planted Genetically Improved	PL		1.3	0.06			0.3	0	Main #1
Planted Genetically Improved	PL		1.3	0.04			0.3	0	Main #1
Planted Genetically Improved	PL		1.3	0.09			0.4	0	Main #1
Planted Genetically Improved	PL		1.3	0.04			0.3	0	Main #1
Planted Genetically Improved	PL		1.3	0.07			0.4	0	Main #1

Planted Genetically Improved	SW		1.3	0.21			0.4	0	Sapling #1
Planted Genetically Improved	SW		1.3	0.19			0.3	0	Sapling #1
Planted Genetically Improved	SW		1.3	0.12			0.3	0	Main #1
Planted Genetically Improved	SW		1.3	0.07			0.3	0	Main #1
Planted Genetically Improved	SW		1.3	0.06			0.3	0	Main #1
Planted Genetically Improved	SW		1.3	0.14			0.4	0	Main #1
Planted Genetically Improved	SW		1.3	0.05			0.3	0	Main #1
Planted Genetically Improved	SW		1.3	0.14			0.3	0	Main #1
Planted Regular	SW		1.3	0.12			0.3	0	Regen #1
Planted Regular	SW		1.3	0.16			0.3	0	Regen #1
Planted Regular	SW		1.3	0.16			0.3	0	Sapling #1
Planted Regular	SW		1.3	0.12			0.3	0	Main #1
Planted Regular	SW		1.3	0.19			0.4	0	Main #1
Planted Regular	SW		1.3	0.11			0.3	0	Main #1
Planted Regular	SW		1.3	0.14			0.4	0	Main #1
Planted Regular	SW		1.3	0.15			0.4	0	Main #1
Planted Regular	SW		1.3	0.18			0.3	0	Main #1