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Project Title: Vegetation Management Options for Establishment of Hybrid Poplar Plantations and their Effect on Nutrient Cycling

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# Table of Contents

Table of Contents ................................................................. i

List of Figures ............................................................................. i

List of Tables ............................................................................... ii

Abstract ..................................................................................... 2

Introduction ............................................................................... 3

Methods ..................................................................................... 4

  - Experiment 1 - Mulch mat herbicide efficacy ................................. 4
  - Experiment 2 - The effect of mulch mat size on tree growth .......... 7
  - Experiment 3 - Nutrient cycling and nutrient pools ...................... 8

Results and Discussion ................................................................ 10

  - Experiment 1 - Mulch mat herbicide efficacy ................................. 10
  - Experiment 2 - The effect of mulch mat size on tree growth .......... 14
  - Experiment 3 - Nutrient cycling and nutrient pools ...................... 18

Summary and Conclusions .......................................................... 24

References .................................................................................. 24

Statement of Expenditures .......................................................... 27

## List of Figures

**Figure 1.** Scale Map of experiment 1 at Menzies Bay, BC. The experimental blocks and plots are labelled and the measurement plot trees are shown................................................................. 5

**Figure 2.** Installation of 60 x 60 cm mulch mats following planting of hybrid poplar cuttings at Menzies Bay ................................................................. 6

**Figure 3.** Uncultivated strip left following cultivation in one direction with a Meri-crusher, Menzies Bay, BC ................................................................. 7

**Figure 4.** Schematic diagram showing the LAI-2000 measurement point layout and the location of the litter traps within a measurement plot................................................................. 9

**Figure 5.** Calibrating LAI-2000 measurement-wand prior to recording light measurement with a 90° view-restrictor................................................................. 10

**Figure 6.** Application of glyphosate herbicide using a back-pack sprayer and bucket shield (June 1996) at hybrid poplar plantation at Menzies Bay BC. Note hybrid poplar are at least twice as tall as competing vegetation in uncultivated strip................................................................. 11

**Figure 7.** One-month following glyphosate application. Note dead vegetation in uncultivated strip, and height of hybrid poplar................................................................. 12

**Figure 8.** Height increment (cm) for the 1999 and 2000 growing seasons. There were no significant differences among treatments................................................................. 13
Figure 9. Average total height following the 1999 and 2000 growing seasons. The trees in the herbicide treated plots are significantly taller than the trees in the other treated plots. ........................................13

Figure 10. Average total diameter at breast height following the 1999 and 2000 growing seasons. The trees in the herbicide treated plots were significantly taller than the trees in the other treated plots for both the 1999 and 2000 growing seasons. ........................................14

Figure 11. Average total height following the 2000 growing season. The graph has been divided by square and rectangular mat sizes. ........................................................................14

Figure 12. Average total dbh following the 2000 growing season. The graph has been divided by square and rectangular mat sizes. ........................................................................15

Figure 13. Average height-increment following the 2000 growing season. Mats are ranked by size (cm²). 15

Figure 14. Average dbh-increment following the 2000 growing season. Mats are ranked by size (cm²). ....16

Figure 15. Maximum and minimum soil temperatures under Arborette control, 60 x 60 cm, 90 x 90 cm, and 240 x 240 cm mats. Note the decreasing amplitude between years. .................................17

Figure 16. Cumulative soil degree days (°C) under Arborette control, 60 x 60 cm, 90 x 90 cm, and 240 x 240 cm mats for the period April 1st to November 1st .........................................................17

Figure 17. Annual litterfall (kg/ha). Bars followed by the same letter within a given year are not significantly different. ......................................................................................19

Figure 18. Nitrogen input (kg/ha) from litterfall. There were no significant differences among treatments. 19

Figure 19. Leaf area index (m²/m²) of hybrid poplars at Menzies Bay, BC. Bars followed by the same letter within a given year are not significantly different. .................................20

Figure 20. Hemispherical photograph taken in the control plot at Menzies Bay, BC. Note the extra leaf area from non-crop vegetation. .................................................................21

Figure 21. Hemispherical photograph taken in the herbicide plot at Menzies Bay, BC. Note the absence of extra leaf area from non-crop vegetation. .....................................................21

Figure 22. Fraction of understory in a hybrid poplar plantation at Menzies Bay, BC over one growing season. Fraction of light was measured using stationary quantum sensors. The lower understory light in the mat treated plots is a result of a understory vegetation. ........................................................................22

List of Tables

Table 1. Summary of selected foliar nutrients. Means within each row, followed by the same letter are not significantly different, based on analysis of variance and Bonferroni’s method (α = 0.05). ........18

Table 2. Extension Products........................................................................................................................................22
Abstract

This project addresses issues relating to Forest Operations and Decision-Support (testing regeneration and stand tending practices for managing broadleaf and mixedwood ecosystems, and developing extension activities to support integrated resource management) and addresses opportunities to maximise yield and return on investment through broadleaf management. Successful establishment of hybrid poplars on both agricultural and forest lands requires intense pre-planting site preparation followed by weed control for at least 2 years. Traditionally, herbicides such as glyphosate have been used in poplar plantations in B.C., however, application of herbicides is not permitted in areas with standing water or in areas close to streams. There is also concern that short rotations may remove nutrients too quickly thereby compromising site productivity and sustainability. This proposal included studies that evaluated and demonstrated the effectiveness of plastic mulch mats and glyphosate herbicide treatments for weed control in hybrid poplar plantations, evaluated the impact of these treatments on poplar performance, and provided baseline data to improve our understanding of nutrient cycling in hybrid poplar plantations over the course of one rotation. The project was conducted at Menzies Bay near Campbell River on Vancouver Island. To date, research findings have been disseminated through one journal article, an article in Woodlot Association Almanac, two extension notes, one progress report, two conference papers/posters, and seven field tours for forestry practitioners and researchers. In addition, the project provided data and support for three co-op student work-term reports. The benefits of this project are being experienced at forest management (woodlot owners and farmers) and policy levels (Ministry of Forest and Agriculture). The primary users of these results are woodlot owners, forest managers and farmers involved with the hybrid poplar management for wood and fibre. This project emphasises the need for vegetation management in this forest type in order to maximise wood production.
Introduction

Demand for wood fibre has led to increased interest in short rotation intensive culture of hybrid poplar. Hybrid poplars are sensitive to weed competition (Bowersox et al. 1992; Aird 1962). Successful establishment of hybrid poplar plantations requires intensive site preparation (Schreiner 1945; Hansen et al. 1983) and post-planting weed control for several years following planting (Bowersox et al. 1992; Hansen et al. 1983; von Althen 1979). Weed control can substantially increase survival (Czapowskyj and Safford 1993; von Althen 1981), height and diameter growth (Lesko and Soos 1976; Schreiner 1945) and foliar nutrient concentrations (Parfitt and Stott 1984; Kennedy 1981) of hybrid poplars. The response to treatment is realised within the first growing season and is evident ten years later (Czapowskyj and Safford 1993).

Mechanical site preparation only provides short-term benefit for poplar establishment and additional post-planting vegetation management is required to control weed species that re-invade the site. A number of options are available to control competing vegetation. Cultivation (disking, furrowing) between plantation rows provides some control of competing vegetation and tree growth is greater than in non-cultivated areas (von Althen 1981). Due to physical limitations of cultivation machinery and the need to minimise tree damage, the area immediately around each tree is left uncultivated and surrounding vegetation competes with poplar whips for soil moisture and nutrients (von Althen 1978). In addition, mechanical cultivation can be constrained by terrain and soil compaction may also be a concern on finer textured soils.

Herbicides, used alone or in combination with cultivation to control weeds, can enhance the growth of crop trees significantly more than with cultivation alone. Compared to other methods of vegetation control, application of herbicides is relatively inexpensive and they can be applied directly to select areas thereby providing spot control of weeds. However, hybrid poplar clones are sensitive to various herbicides (Netzer and Hansen 1992; Akinyemiju 1982) and time of year of application is critical to poplar establishment (Hansen et al. 1984). Glyphosate herbicide provides effective weed control with limited adverse effects on tree survival and growth but is difficult to apply without damaging actively growing hybrid poplar whips. Leaf damage due to overspray, even when shielded sprayers are used, can occur and leads to reductions in tree height and survival (Hansen and Netzer 1984; Hansen et al. 1984). Tree damage can be minimised when Glyphosate is broadcast sprayed between late October and early May, and providing that trees are leafless shielding is not required. Various studies (Netzer and Hansen 1992; Hansen and Netzer 1985; Danfield et al. 1984) have demonstrated 100% survival using this method. Application rates from 1.1 to 2.1 kg-active ingredient/ha provide effective weed control, and tree growth is up to 70% greater than in unsprayed plots (Netzer and Hansen 1992; Hansen and Netzer 1985). A recent study in coastal British Columbia has demonstrated volume increases of 300 to 400 percent in sprayed plots over unsprayed controls (van Oosten pers. comm.). Application timing appears to be most critical during the first 3 growing seasons following planting, after which glyphosate can be applied anytime throughout the growing season without any detrimental effects to the trees (Netzer and Hansen 1992).

Although herbicides can be an economical and effective method of weed control there is growing reluctance on the part of many land owners and farmers to use them. Permits,
and training are required before herbicides can be applied. In addition, herbicide application is not permitted in areas close to streams or standing water.

Opaque polyethylene mulch mats placed around the tree stem act as a mechanical barrier and can provide effective weed control in hybrid poplar plantations. Mulch mats suppress vegetation growth, slow evaporation of soil moisture, and increase soil temperature. The combination of these three factors leads to increased root production (≈ 200%), nutrient uptake (≈ 25%) and tree shoot growth (≈ 25%) (Parfitt and Stott 1984). Research has shown hybrid poplar survival and growth to be greater with mulch mats than other methods of vegetation control (Blain 1984; Bowersox and Ward 1970).

Presently, there is a need for information on the effects of polyethylene mulch mats on weed control, survival, growth and yield of hybrid poplar plantations in British Columbia. The objectives of this study were 1) to evaluate the effectiveness of polyethylene mulch mats and glyphosate herbicide treatment on hybrid poplar growth and survival; 2) to evaluate the effectiveness of two types of mulch mat of varying sizes on hybrid poplar growth and survival; and, 3) to evaluate the impact of different vegetation management regimes on site nutrient cycling over the course of one rotation.

Methods

The experimental plantation is located in the very dry maritime coastal western hemlock (CWHxWi) biogeoclimatic subzone near Menzies Bay (50°07'00"N), on Vancouver Island, British Columbia. The site is flat and is situated approximately 100 m above sea level. A Douglas-fir forest, which previously occupied the site, was harvested in winter 1993 - 1994. The forest floor and other woody material was bulldozed into windrows and placed to the north, south and west sides of the site. The mineral soil was subsequently ploughed to a depth of 75 - 85 cm with a wing-tipped sub-soiler. Soil analysis indicates that the soil was originally a humo-ferric podzol. Hybrid poplar (Populus trichocarpa × P. deltoides) rootless cuttings, 40-cm long, were operationally planted at 3 m × 3 m spacing in March 1995.

Experiment 1 - Mulch mat herbicide efficacy

This experiment used a randomised complete block design with 5 blocks and 3 treatments, with each treatment applied once in each block, for a total of 15 treatment plots (Figure 1). Blocking was chosen because of possible soil and moisture gradients on the site. The treatment plot measured approximately 36 m × 36 m and consisted of 144 poplar cuttings (12 rows × 12 cuttings). There were no untreated areas between plots. To minimise a possible edge effect, the inner 36 cuttings (6 rows × 6 cuttings) of each plot were tagged and used as sample trees. This provided a 10.5 m treated buffer between measurement trees and the adjacent treatment plot. The three treatments were: 1) untreated control (no weed control within planted tree rows); 2) Green polyethylene mulch mats (60 cm × 60 cm); and, 3) glyphosate herbicide (2% v/v [2.1 kg active ingredient/ha]).
Figure 1. Scale Map of experiment 1 at Menzies Bay, BC. The experimental blocks and plots are labelled and the measurement plot trees are shown.
The mats were installed in April 1995 just after planting of the poplar cuttings (Figure 2). The mats were 2 mm thick and had holes punched into the plastic approximately every 5 cm to allow the exchange of air and water with the soil.

Figure 2. Installation of 60 x 60 cm mulch mats following planting of hybrid poplar cuttings at Menzies Bay.

All treatment plots were mechanically cultivated twice yearly (May and September) in one direction (East-West) to a depth of 15 cm using a Meri crusher with a 2.5 m path from 1995 to 1998. This practice left an uncultivated strip between trees running in the same direction as the cultivation (Figure 3). The uncultivated strip was approximately 1 m wide, and represented approximately one third (0.04 ha) of the total plot area (0.13 ha). Herbicide was applied to this area in the herbicide treatment plots. The predominant target species (non-crop vegetation) included Alnus rubra, Rubus parviflorum, Rubus spectabilis, Salix sp., Equisetum spp., Hyparrachium radicula, and various grass species.

Herbicide was not applied during the 1995 growing season because of the extensive site preparation prior to planting which resulted in slow regeneration of non-crop vegetation. Glyphosate herbicide was applied to the uncultivated strips between the poplars in mid-June 1996 and 1997, at a rate of 2.1 kg·a.i./ha (2 L glyphosate/100L spray solution) using a backpack sprayer. A plastic bucket shield, made from a plastic-40-gallon drum split in half vertically, was used to protect poplar whips from over-spray. The herbicide solution was applied until vegetation was thoroughly wetted. Herbicide was not applied during the 1998 growing season due to a lot of rainfall in the summer.
Figure 3. Uncultivated strip left following cultivation in one direction with a Meri-crusher, Menzies Bay, BC.

Initial root collar diameter and height were measured immediately following planting. Tree measurements including root collar diameter [1995 only], diameter at breast height [1995-present] and height were measured after each growing season. Root collar diameter (RCD) and total height were recorded in April 1995. RCD, diameter at breast height (DBH) and height were measured following each growing season from 1995-2000. Annual growth increment was calculated by subtracting the previous year’s growth measurements from the current year’s growth measurements.

Percent cover and height of vegetation within a 25 cm radius of each poplar was assessed in early summer of 1995-2000 and recorded for each species exceeding 5% cover.

The data were analysed using analysis of variance techniques for a randomised complete block design (Systat 1992) with treatment being the main effect. The multiple trees per plot were nested within the experimental unit (plot). Data were analysed separately by year. Prior to the analysis of variance the data were tested for homogeneity of variances. Differences among means were considered significant if p ≤ 0.05. If a significant difference among means occurred, Bonferroni’s method (Milliken and Johnson 1992) was used to compare treatment means.

**Experiment 2 - The effect of mulch mat size on tree growth**

A relatively homogeneous site, situated in the south western corner of the experimental area (adjacent to Experiment 1), consisting of 12 rows of 12 trees was chosen for this experiment. This is a factorial experiment laid out in a completely randomised design with two factors: mat type (two levels) and mat size (ten levels), for a total of 20
treatment combinations replicated five times each (100 experimental units). The factors and levels were as follows:

1) Mat type:
   i) green mats
   ii) black mats.

2) Mat Size:

<table>
<thead>
<tr>
<th>Mat size (cm)</th>
<th>Area (cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>control</td>
<td>0</td>
</tr>
<tr>
<td>60x60</td>
<td>3600</td>
</tr>
<tr>
<td>90x90</td>
<td>8100</td>
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<tr>
<td>120x120</td>
<td>14400</td>
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<td>180x180</td>
<td>32400</td>
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<td>60x240</td>
<td>14400</td>
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<tr>
<td>90x240</td>
<td>21600</td>
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<td>120x240</td>
<td>28800</td>
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<tr>
<td>180x240</td>
<td>43200</td>
</tr>
<tr>
<td>240x240</td>
<td>57600</td>
</tr>
</tbody>
</table>

The mat sizes were chosen to cover as wide a range of possible mat sizes in order to provide enough data to construct a response surface between mulch mat size and poplar growth. Each treatment combination was replicated five times. Both mat types were installed at the same time during mid-April 1995, and rectangular mats were laid east to west.

The inner 10 rows of 10 trees were used as the experimental area. Each tree was designated as an experimental unit and numbered. Root collar diameter (rcd) and total height was recorded at time of mat installation. Red, diameter at breast height (dbh) and height were re-measured following each growing season from 1995-2000. Soil temperature and moisture were recorded throughout the growing season using soil temperature probes and a CR10 data logger. Forty pairs of probes (one gypsum block and one temperature sensor) were placed within a 20 cm radius of the tree and installed to a depth of 15 cm. Each pair of probes were placed near each control tree and all trees with mat sizes of 60 x 60 cm, 90 x 90 cm and 240 x 240 cm.

**Experiment 3 - Nutrient cycling and nutrient pools**

This study was conducted in plots established for Experiment 1, and data were analysed using a randomised complete block design for within year data. Five soil samples were collected, at a depth of 15 cm, in each plot prior to each growing season and at the end of each growing season. Samples were analysed for exchangeable Ca, Mg, K, available P, mineralizable N, total N, and pH. Data will help provide an estimate of soil nutrient pools over one rotation.

Ten 0.8 m² litter traps were placed within each plot every fall from 1996 to 2000. Data was analysed using a randomised complete block design and analysis of variance. For the decomposition studies, fresh litter was collected in the fall of 1996 and 560 litter
bags (15 plots x 6 bags/plot x 2 collections/year x 3 years) were constructed. Litter bags were installed in the winter of 1996. The first litter bag collection was in April 1997 and the last was January 2000. Following each collection the leaves were analysed for macro-nutrients. The data will provide a baseline which will eventually be used to estimate nutrient inputs to the forest soil and rates of decay over the course of the rotation.

The eighth leaf down or the first mature leaf in the was sampled at the beginning of the growing season (when all leaves are fully flushed), mid growing season and at the end of the growing season just prior to abscission. The leaves were analysed for macro-nutrients. The data will assist in determining the efficiency of internal nutrient cycling of hybrid poplars and the internal nutrient pool. The leaves were sampled in 1996, 1997, 1999, and 2000, sampling is scheduled for 2004.

In each of the 15 plots Leaf Area Index (LAI) measurements were recorded from 25 points (five rows of five points) using LAI-2000 instrumentation. Each point was located between planting rows at the epicentre of four trees (Figure 4). LAI measurements were recorded in the summer of each 1997, 1998, 1999 and 2000 (Figure 5). LAI measurements will be used to estimate leaf biomass.

![Diagram showing LAI measurement points and litter trap locations](image)

**Figure 4.** Schematic diagram showing the LAI-2000 measurement point layout and the location of the litter traps within a measurement plot.
Figure 5. Calibrating LAI-2000 measurement-wand prior to recording light measurement with a 90° view-restrictor.

Results and Discussion

Experiment 1 - Mulch mat herbicide efficacy

The mats significantly improved tree growth during the first growing season (1995). This growth was probably attributable to higher soil temperatures and moisture under the mats which enhanced root growth and subsequent nutrient uptake. The mats also acted as a mechanical barrier to the establishment of non-crop vegetation, providing a ‘competition free’ zone for the hybrid poplar roots to grow in. The beneficial effect of the mats on tree growth was only evident for the first growing season (1995), with no apparent lasting effect on tree growth (height and diameter). There are a couple of plausible reasons for this: 1) by the beginning of the second growing season (1996) the poplar roots had grown well beyond the mat boundaries, and the proportion of tree roots under the mats was small compared to the total root area of the tree. This resulted in the matted trees experiencing similar below-ground competition for resources from the rapidly establishing non-crop vegetation. This competition would have probably been similar to that experienced in the non-matted control plots; and, 2) the non-crop vegetation was establishing around the periphery of each mat with roots competing for resources in the ‘competition free’ zone under the mats. By the beginning of the second growing season (1996), the non-crop vegetation was well established within planting rows (non-cultivated area). Although there were no significant differences in total poplar height among treatments at the end of the 1996 growing season, the height increment of trees in the herbicide treated plots (+234 cm) was significantly greater than in the other
treatments (+206 cm). Competition for light was not an issue in this instance because all the poplars in all plots were at least twice as tall as the non-crop vegetation prior to herbicide application (Figure 6).

![Figure 6](image)

*Figure 6. Application of glyphosate herbicide using a back-pack sprayer and bucket shield (June 1996) at hybrid poplar plantation at Menzies Bay BC. Note hybrid poplar are at least twice as tall as competing vegetation in uncultivated strip.*

These findings suggest that the non-crop vegetation in the 1.0-1.5 × 3.0 m uncultivated strips provide below-ground competition for resources which can significantly reduce the growth of the hybrid poplars (Figure 7). The second glyphosate application further improved tree growth, and by the end of the 1997 growing season, trees in the herbicide plots had significantly greater total height and dbh than trees in the other two treatments. These significant differences were also reflected in both the height and diameter increments for the 1997 growing season. This trend did not continue, and by the end of the 1998 growing season there were only significant differences in total height and dbh, and not annual increments, between the herbicide and the other two treatments. After four growing seasons hybrid poplar treated with glyphosate were significantly taller (983 cm) than either the mat (915 cm) or control treated plots (902 cm). Diameter at breast height was also significantly greater in the herbicide treated plots (88 mm) than in either the mat (78 mm) or control (77 mm) treated plots. Total volume was also significantly greater in herbicide plots (23 m³/ha) than in either the mat (17 m³/ha) or control (17 m³/ha) plots. Basal area, and total volume were 14% and 37%, respectively, greater in the herbicide plots than in the mat and control plots following the fourth growing season. These appear to be large gains in volume, especially since glyphosate was only applied to
approximately one-third of the plot (0.04 ha) area in each herbicide treatment plot (0.1296 ha).

At the end of the 1999 growing season there was a large wind-event which damaged approximately 200 of the 540 measurement trees. The damage was across the entire study area. In some cases, measurement trees lost in excess of 3 m height-growth. The broken tops were matched with their respective trees and height increments calculated. There were no significant differences in height increment for both the 1999 and 2000 growing seasons (Figure 8).

Average total height (Figure 9) and diameter (Figure 10) of trees in the herbicide plot is significantly greater than in the control and mat treated plots following the 2000 growing season. The total heights would have been approximately +2-3 m (in all plots) if the trees had not been damaged by wind.

At this point in the rotation it is difficult to predict the long-term impacts of these treatments on volume at harvest age. These results emphasise the importance of controlling non-crop vegetation during the early establishment of hybrid poplar plantations.
**Figure 8.** Height increment (cm) for the 1999 and 2000 growing seasons. There were no significant differences among treatments.

**Figure 9.** Average total height following the 1999 and 2000 growing seasons. The trees in the herbicide treated plots are significantly taller than the trees in the other treated plots.
Figure 10. Average total diameter at breast height following the 1999 and 2000 growing seasons. The trees in the herbicide treated plots were significantly taller than the trees in the other treated plots for both the 1999 and 2000 growing seasons.

Experiment 2 - The effect of mulch mat size on tree growth

The data were analysed as a factorial experiment laid out as a completely randomised design. There was no mat type by mat size interaction which greatly facilitated interpretation. In general, trees treated with square mats had greater growth than rectangular mats (Figures 11 and 12), and height and dbh increased with increasing mat area (Figure 13 and Figure 14).

Figure 11. Average total height following the 2000 growing season. The graph has been divided by square and rectangular mat sizes.
Figure 12. Average total dbh following the 2000 growing season. The graph has been divided by square and rectangular mat sizes.

Figure 13. Average height-increment following the 2000 growing season. Mats are ranked by size (cm²).
Figure 14. Average dbh-increment following the 2000 growing season. Mats are ranked by size (cm²).

As in Experiment 1 there was a wind event that broke the tops off 55 of the 100 measurement trees. As a result total height should have been 2-3 m greater than reported. Mat sizes of 120 x 120 cm appears to give the best overall growth response. Total height (including broken tops) following the 1999 growing season of trees treated with 120x120 cm mats were +1 m taller than trees treated with 90x90 cm mats, although this difference was not significant. Mat size had an influence on soil temperature, the larger mats tended to mitigate diurnal fluctuations in temperature and slowed down the cooling of the soil (Figure 15). This could have had a positive effect on tree growth by warming up the soil quicker than non-matted trees, and providing more degree days for tree growth. As the plantation aged the amplitude of the seasonal fluctuation in soil temperature was dampened, this was most likely the result of increased understorey vegetation. Cumulative soil degree-days were calculated for the period April 1st and November 1st (Figure 16).
Figure 15. Maximum and minimum soil temperatures under Arbotec control, 60 x 60 cm, 90 x 90 cm, and 240 x 240 cm mats. Note the decreasing amplitude between years.

Figure 16. Cumulative soil degree days (°C) under Arbotec control, 60 x 60 cm, 90 x 90 cm, and 240 x 240 cm mats for the period April 1st to November 1st.
Experiment 3 - Nutrient cycling and nutrient pools

A summary of selected foliage nutrients is presented in Table 1. Percent potassium was significantly greater in the 1997 fresh foliage in the herbicide treated plots than in the other plots. Percent phosphorous was significantly greater in the 1997 mature foliage in the herbicide treated plots than mat treated plots. There were no significant differences in % nitrogen. These findings suggest that the herbicide and mat treatments had no appreciable impact on nutrient concentrations in the foliage.

Table 1. Summary of selected foliar nutrients. Means within each row, followed by the same letter are not significantly different, based on analysis of variance and Bonferroni’s method ($\alpha = 0.05$).

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Year</th>
<th>Season</th>
<th>Control</th>
<th>Treatment</th>
<th>Mat</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Potassium</td>
<td>1997</td>
<td>Fresh</td>
<td>0.993 (0.235) b</td>
<td>1.247 (0.207) a</td>
<td>1.118 (0.143) ab</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mature</td>
<td>1.089 (0.360)</td>
<td>1.242 (0.203)</td>
<td>1.065 (0.204)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Senesc.</td>
<td>0.829 (0.276)</td>
<td>1.030 (0.346)</td>
<td>0.825 (0.261)</td>
</tr>
<tr>
<td></td>
<td>1998</td>
<td>Fresh</td>
<td>1.308 (0.204)</td>
<td>1.438 (0.238)</td>
<td>1.291 (0.167)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mature</td>
<td>1.280 (0.248)</td>
<td>1.283 (0.223)</td>
<td>1.192 (0.258)</td>
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<td></td>
<td></td>
<td>Senesc.</td>
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<td>1.164 (0.291)</td>
<td>0.972 (0.288)</td>
</tr>
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<td>1999</td>
<td>Fresh</td>
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<td>1.043 (0.125)</td>
<td>1.018 (0.106)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mature</td>
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<td>1.287 (0.164)</td>
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</tr>
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<td></td>
<td></td>
<td>Senesc.</td>
<td>1.996 (0.287)</td>
<td>1.965 (0.395)</td>
<td>1.963 (0.358)</td>
</tr>
<tr>
<td>% Phosphorus</td>
<td>1997</td>
<td>Fresh</td>
<td>0.276 (0.024)</td>
<td>0.280 (0.024)</td>
<td>0.277 (0.036)</td>
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<td>Mature</td>
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<td>0.279 (0.045) b</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Senesc.</td>
<td>0.075 (0.013)</td>
<td>0.078 (0.019)</td>
<td>0.070 (0.013)</td>
</tr>
<tr>
<td></td>
<td>1998</td>
<td>Fresh</td>
<td>0.411 (0.027)</td>
<td>0.413 (0.030)</td>
<td>0.380 (0.042)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mature</td>
<td>0.234 (0.054)</td>
<td>0.224 (0.062)</td>
<td>0.217 (0.046)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Senesc.</td>
<td>0.175 (0.061)</td>
<td>0.189 (0.064)</td>
<td>0.151 (0.059)</td>
</tr>
<tr>
<td></td>
<td>1999</td>
<td>Fresh</td>
<td>0.233 (0.026)</td>
<td>0.227 (0.021)</td>
<td>0.226 (0.018)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mature</td>
<td>0.212 (0.021)</td>
<td>0.192 (0.021)</td>
<td>0.200 (0.023)</td>
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<tr>
<td></td>
<td></td>
<td>Senesc.</td>
<td>0.330 (0.066)</td>
<td>0.333 (0.064)</td>
<td>0.327 (0.055)</td>
</tr>
<tr>
<td>% Nitrogen</td>
<td>1997</td>
<td>Fresh</td>
<td>3.265 (0.436)</td>
<td>3.583 (0.308)</td>
<td>3.445 (0.375)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mature</td>
<td>2.200 (0.293)</td>
<td>2.362 (0.304)</td>
<td>2.197 (0.262)</td>
</tr>
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<td></td>
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<td>Senesc.</td>
<td>0.075 (0.013)</td>
<td>0.078 (0.019)</td>
<td>0.070 (0.013)</td>
</tr>
<tr>
<td></td>
<td>1998</td>
<td>Fresh</td>
<td>4.187 (0.402)</td>
<td>4.331 (0.409)</td>
<td>4.155 (0.518)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mature</td>
<td>2.335 (0.421)</td>
<td>2.186 (0.333)</td>
<td>2.233 (0.373)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Senesc.</td>
<td>1.403 (0.253)</td>
<td>1.403 (0.206)</td>
<td>1.308 (0.228)</td>
</tr>
<tr>
<td></td>
<td>1999</td>
<td>Fresh</td>
<td>3.076 (0.230)</td>
<td>3.021 (0.294)</td>
<td>3.019 (0.223)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mature</td>
<td>2.510 (0.203)</td>
<td>2.390 (0.236)</td>
<td>2.379 (0.226)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Senesc.</td>
<td>2.158 (0.218)</td>
<td>2.055 (0.180)</td>
<td>2.129 (0.210)</td>
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</table>

Litterfall was significantly greater in the herbicide plots in years 1997, 1998 and 1999. However there were no significant differences among treatments in year 2000 (Figure 17).
Figure 17. Annual litterfall (kg/ha). Bars followed by the same letter within a given year are not significantly different.

These results suggest that canopy closure has occurred and that total leaf biomass is culminating. Although there were significant differences in litterfall for 1997 to 1999 growing season, this did not translate into greater nutrient inputs. In fact there were no significant differences among treatments (Figure 18).

Figure 18. Nitrogen input (kg/ha) from litterfall. There were no significant differences among treatments.
The mineral soil was also sampled and there were no significant differences among treatments, or trends across years. These findings suggest that there has been no effect to date on soil nutrient capital.

Leaf area index was measured in an attempt to quantify mature foliar biomass. A relationship between leaf area and weight was developed (Lawrence 1997), and LAI was found to be strongly correlated with basal area (Lawrence 1998). Leaf area had stabilised by the 1999-2000 growing seasons indicating canopy closure. Although there were no differences in leaf biomass, the LAI was significantly greater in the control and mat plots (Figure 19) than in the herbicide plots, and was most likely a result of more non-crop vegetation in the control and mat treated plots.

![Figure 19](image)

Figure 19. Leaf area index (m²/m²) of hybrid poplars at Menzies Bay, BC. Bars followed by the same letter within a given year are not significantly different.

Hemispherical photographs (Figures 20 and 21) were also used to help quantify leaf area and were found to be very poorly correlated with LAI measures (Lawrence 1998) because it was difficult to partition-out leaf area from non-crop vegetation. The effect of this non-crop vegetation on understory light is easily demonstrated when the seasonal understorey light (recorded from light sensors) is plotted for the mat and herbicide plots. There is much less understory light (Figure 22) in the mat treated plots (red line) than in the herbicide treated plots (blue line), and this difference can be attributed to greater understory leaf area in the growing season and wood area in the winter.
Figure 20. Hemispherical photograph taken in the control plot at Menzies Bay, BC. Note the extra leaf area from non-crop vegetation.

Figure 21. Hemispherical photograph taken in the herbicide plot at Menzies Bay, BC. Note the absence of extra leaf area from non-crop vegetation.
Figure 22. Fraction of understorey in a hybrid poplar plantation at Menzies Bay, BC over one growing season. Fraction of light was measured using stationary quantum sensors. The lower understorey light in the mat treated plots is a result of a understorey vegetation.

Extension

The interim results of this project have been extended to various end-user groups using a multitude of media types. We have extended results through Extension Notes, site tours, workshops, conference proceedings, journal articles and co-operative term reports. Our target audiences have been District Field Staff, Policy makers and Forest Researchers. We have developed web pages highlighting these projects and have linked them into the Research Branch’s website. We have also provided a number of opportunities to train budding forest researchers through co-operative student positions and their respective term-projects. The extension products produced are in listed in Table 2. These extension efforts have received province-wide and world-wide responses from the forest and research communities. Additional extension products are in preparation which will provide further exposure of project results to the scientific and forestry communities.

Table 2. Extension Products

<table>
<thead>
<tr>
<th>Publications</th>
<th>End users</th>
</tr>
</thead>
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<td>Reference</td>
<td>Audience</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------</td>
<td>---------------------------------------</td>
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<tr>
<td>Thomas, K.D. 2000. Woodlot Association Almanac article</td>
<td>BC foresters and Woodlot owners</td>
</tr>
<tr>
<td>Thomas, K.D. and P.G. Comeau. 1998. Vegetation management options for establishment of hybrid poplar plantations and their effect on nutrient cycling. BC Min. For. Extension Note 25.</td>
<td>BC foresters and researchers</td>
</tr>
</tbody>
</table>

**Sites Tours/Workshops**

- TASS Modelling Group 2000
- Campbell River Foresters 2000
- Port McNeill Foresters October 1999
- Forest Geneticists 1998
- Poplar Council of Canada 1997
- Hardwood Silviculture Committee Meeting - Site tour 1996
- Expert Committee on Weeds (ECW) Conference - 1996
- Poplar Growers Site Tour 1996
- Tactical Advisory Committee Meeting - Site tour 1996

**Other Products**

- WebPages - design and implementation on Research Branch Website

**In Preparation**

- Thomas, K.D. and W.J. Reid. Vegetation management using
Summary and Conclusions

This project was designed to study the effects of vegetation management on hybrid poplar growth and the effect of short rotation management on nutrient pools. The innovative aspects of the project include using opaque polyethylene mats as an alternative to herbicide. We have achieved two of the objectives set out in our original proposal and laid the foundation for the completion of the 3rd which will have to be followed-up over the course of the rotation and over successive rotations. We have obtained information on the growth of hybrid poplar in response to different methods of vegetation management. While the nutrient cycling information is baseline and needs to be followed through the course of a full rotation, forest managers can apply short-term vegetation management results to effectively and productively managing these plantations. These findings suggest that the non-crop vegetation in the 1.0-1.5 x 3.0 m uncultivated strips provide below-ground competition for resources which can significantly reduce the growth of the hybrid populars. Basal area, and total volume were 14% and 37%, respectively, greater in the herbicide plots than in the mat and control plots following four growing seasons. These appear to be large gains in volume, especially since glyphosate was only applied to approximately one-third of the plot (0.04 ha) area in each herbicide treatment plot (0.1296 ha). At this point in the rotation it is difficult to predict the long-term impacts of these treatments on volume at harvest age. However, these results emphasise the importance of controlling non-crop vegetation during the early establishment of hybrid poplar plantations. The project was conducted in the Campbell River Forest District and the benefits of the project are being experienced throughout coastal BC. The end-users of these results are forest practitioners, woodlot managers and forest researchers. Current benefits experienced include: increased awareness of the importance of vegetation management in hybrid poplar plantations to encourage maximum wood production and increase yield, and that opaque polyethylene mats greater than 120 x 120 cm may be an effective alternative to glyphosate herbicide in south coastal plantations.

References


Statement of Expenditures