Project Title: **Improving the Efficiency of Planting, Tending and Harvesting Farm Grown Trees for Energy**

Contract Number: RD-50, Milestone Number: 14 Report Date: 12/3/07

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Congressional District: 3 (Corporate office: Rogers, MN)
Congressional District: 7 (Project Farm location: Graceville, MN)
Congressional District: 6 (Equipment Building Location: Big Lake, MN)

**MILESTONE 14 - SUMMARY REPORT**

**Annual Tending and Monitoring of Trees**

**Executive Summary:**

The approximately 80 acres of hybrid poplars trees planted in two 40 acre fields near Graceville, MN in June of 2007 were tended and monitored throughout the summer and the trees were evaluated for fall density levels and height in October 2007. The good rainfall in May and early June prior to the planting of the trees and the good moisture holding capacity of the soil, helped the trees to survive the dry conditions following planting. The final density in the west field was 75% and in the east field was 93%. The mean heights of 2.9 feet in the west field and 3.8 feet in the east field are significantly different based on statistical analysis. Maximum heights in both fields were nearly 7 feet. There was some chlorosis of trees observed in both fields, but it only seemed to affect growth in the west field. There were a large number of variables affecting final density and growth, including time of planting, nature of planting (hand vs. machine), size and condition of the cuttings at time of planting, micro-field soil type and pH differences, differences in weed control effectiveness, and differences in timing of mowing in different sections of the field. Variables of this nature are a normal circumstance when planting at a commercial scale and testing new equipment. The machine planted and hand planted trees showed similar levels of variation, thus there did not appear to be any adverse affects specifically of machine planting on the survival and growth of trees. The final density and growth (a combination of survival and original planting success) was exceptionally good given the very serious drought conditions that occurred in western Minnesota during the summer of 2007.
Technical Progress Milestone 14a: Completion and field-testing, monitoring, fertilizer and herbicide applications for second growing season (including assessment of tree growth and survival of second plantings)

Introduction

The Graceville planting site, consisting of two fields divided by a highway, is in the middle of a primarily agricultural area in western MN (Appendix A, Fig. 1). Most of the land in the foreground of the photo is owned by the Frisch family. Dean Frisch, one of the owners, worked closely with the project to complete the site preparation and planting of the trees (Fig. 2). Immediately adjacent to the planting sites is a lake to the west of the western field (Fig. 3), and land enrolled in the Conservation Reserve Program to the north and east of the eastern field (Fig. 4). The aerial photos of the area were taken in early October, 2007, just prior to collecting fall measurements.

As previously reported in Milestone Report 12, heavy rainfall occurred in May and early June delaying the planting of all crops in Western Minnesota until the second week of June. Machine planting of the hybrid poplar trees began as soon as possible (approximately 1 week) after the heavy rains stopped. A light tillage of the of the field was done to help with drying of the surface of the soil, but a 12 row strip was left untilled in each field as an experiment to evaluate possible effects on planting and growth. Hand planters were hired to assist with a timely planting of both fields, while the newly designed planter and GPS guidance systems were simultaneously being tested on portions of the west field. The planting of the two fields in Graceville was accomplished over a three week period with the first cuttings being machine planted on June 9, 2007 and the last cuttings hand planted on July 5, 2007 at nursery spacing in a small portion of the field. Approximately 130,000 hybrid poplar trees slips were planted altogether.

Post-planting Tending and Monitoring of Hybrid Poplars Planted in Graceville, MN

Tending of the fields included both pre-planting and post-planting operations. The pre-planting tending involved one application glyphosate on May 14, 2007. By the time of the intended planting date of June 2, the weeds appeared to be under relatively good control by comparison to a small strip that was missed by the sprayer (Fig. 5). Post-planting tending began after the completion of the hand planted area in late June. Not all portions of the fields were sprayed due either to the fact that some leaf out had already begun in portions of the field planted in early June, or because the applicator ran out of spray mixture before the entire area was sprayed. The unsprayed sections occurred only on the west field. The east field was fully sprayed.

The post-planting herbicide sprays were a mixture of Scepter 70 DG applied at 2.8 oz/acre and Pendulum 3.3 EC applied at 1.5 quarts/acre. The rates of application were not the highest labeled rates, but were rates similar to those commonly used on other hybrid poplar in that part of Minnesota. Decisions on the herbicide types and rates of application were made after thoroughly researching the literature and consulting with local commercial hybrid poplar tree crop managers. The post-plant herbicides were not very effective, primarily because the selected herbicides needed to be “rained in” to achieve full effectiveness. There was no rain after herbicide application for several weeks. However, it was apparent that there was an interaction between the herbicide effectiveness and tillage. Most of the portions that had been lightly tilled contained mostly broad-leaved weeds (Fig. 6) that are not necessarily a serious problem, while the untilled rows contained a heavy cover of grass that was more highly competitive with the trees (Fig. 7). The strip of heavy grass cover (light colored areas) remained highly visible in the aerial
photos taken in early October (Figs. 3 & 4). There were also heavy patches of grass outside of the non-tilled area so the interaction between the herbicide effectiveness and tillage was not totally clear-cut.

The mid-season weed control strategy continued to be mowing between the rows with a brush cutting mower. The mower had been modified to fit between the 5 ft rows. Mowing the weeds on both fields occurred over a several week period, but the first emphasis was on the area in the west field that had not received any post-planting herbicides. At the time the mowing started, the weeds in the non-herbicided portion of the field were about waist-high. Flags were placed in each row to aid in identifying the rows (Fig. 8). As the weeds were removed from either side of the tree rows, it was possible to see healthy looking trees in the non-herbicided areas (Fig. 9). Mowing was only done in the north-south direction since the lack of crosschecking in the hand-planted areas prevented mowing in the east-west direction (Fig. 10).

Rainfall information (Table 1) was obtained from the farmers co-operative in the nearby village of Dumont. Essentially no rainfall fell for at least 6 weeks after planting.

<table>
<thead>
<tr>
<th>Month</th>
<th>Rainfall (inches)</th>
<th>notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>May</td>
<td>4.46</td>
<td></td>
</tr>
<tr>
<td>June</td>
<td>4.21</td>
<td>All rainfall in first week</td>
</tr>
<tr>
<td>July</td>
<td>0.65</td>
<td></td>
</tr>
<tr>
<td>August</td>
<td>2.47</td>
<td>Rainfall in later half of month</td>
</tr>
</tbody>
</table>

Growth and Survival/density Results

Forty tree measurement plots were established in each field, or approximately 1 per acre – with some exceptions to insure all sources of variation were appropriately represented. Figures 11 and 12 show the approximate location of the measurement plots in each field. The plots have been marked with flags so that they can be relocated in following years (Fig. 13).

The first year end-of-season density of the trees (Table 2) is based on the number of trees that could be located within the 10-tree rows at each measurement plot location and is reported as a function of field and transect. Percent density is reported rather than percent survival, since some of the loss in expected tree density happened at the time of planting rather than by mortality during the growing season. This is particularly true in the west field where hand planting density was closer to 5 ft x 5.3’ rather than 5 ft x 5ft, resulting in only 94% of the planned density of 1742 trees per acre. The hand planted transects (2, 3, 4) of the west field are adjusted to account for lower initial density. The east field results did not need to be adjusted since trees were planted in the 5ftx5ft crosschecked intersections in most sections of the field. The distinctly lower % density in transect 7a in the east field, and 1b in the west field, shows the effect of strong grass competition on hybrid poplar survival.
Table 2. Density of trees in October 2007, four months after planting.

<table>
<thead>
<tr>
<th>N-S Transect</th>
<th>East Field</th>
<th>West Field</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Expected No. trees</td>
<td>Actual No. trees</td>
</tr>
<tr>
<td>1</td>
<td>40</td>
<td>35</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>45</td>
</tr>
<tr>
<td>3</td>
<td>60</td>
<td>54</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>39</td>
</tr>
<tr>
<td>5</td>
<td>40</td>
<td>38</td>
</tr>
<tr>
<td>6</td>
<td>60</td>
<td>57</td>
</tr>
<tr>
<td>7a¹</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>7b²</td>
<td>40</td>
<td>38</td>
</tr>
<tr>
<td>8</td>
<td>60</td>
<td>59</td>
</tr>
<tr>
<td>Summary</td>
<td>410</td>
<td>383</td>
</tr>
</tbody>
</table>

1 Transect 7a includes those plots in transect 7 that were inside of the no-till/grassy areas.
2 Transect 7b includes those plots in transect 7 that were inside of the no-till grassy area.
3 Transect 1b is actually just one plot placed in the middle of the heavy grass strip.

Table 3. Average heights of trees by field and transect and comparison statistics.

<table>
<thead>
<tr>
<th>N-S Transect</th>
<th>East Field</th>
<th>West Field</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. trees measured</td>
<td>Height in cm (avg)</td>
</tr>
<tr>
<td>1</td>
<td>40</td>
<td>146.8</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>124.5</td>
</tr>
<tr>
<td>3</td>
<td>60</td>
<td>95.5</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>126.0</td>
</tr>
<tr>
<td>5</td>
<td>40</td>
<td>121.1</td>
</tr>
<tr>
<td>6</td>
<td>60</td>
<td>116.2</td>
</tr>
<tr>
<td>7a¹</td>
<td>20</td>
<td>61.5</td>
</tr>
<tr>
<td>7b²</td>
<td>40</td>
<td>121.1</td>
</tr>
<tr>
<td>8</td>
<td>60</td>
<td>110.3</td>
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<tr>
<td>Summary</td>
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<td>114.8</td>
</tr>
<tr>
<td>Maximum</td>
<td>208</td>
<td>6.8</td>
</tr>
<tr>
<td>Minimum</td>
<td>10</td>
<td>0.3</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>44.95</td>
<td>1.5</td>
</tr>
<tr>
<td>Standard Error</td>
<td>2.31</td>
<td>0.1</td>
</tr>
<tr>
<td>95% Confidence level</td>
<td>4.36</td>
<td>0.1</td>
</tr>
</tbody>
</table>

1 Transect 7a includes those plots in transect 7 that were outside of the no-till/grassy areas.
2 Transect 7b includes those plots in transect 7 that were inside of the no-till grassy area.
3 Transect 1b is actually just one plot placed in the middle of the heavy grass strip.
Table 4. Comparison of heights of chlorotic and non-chlorotic trees.

<table>
<thead>
<tr>
<th>Field</th>
<th>No. chlorotic trees measured</th>
<th>Height in cm</th>
<th>Height in ft</th>
<th>N-S Transect</th>
<th>No. non-chlorotic trees measured</th>
<th>Height in cm (avg)</th>
<th>Height in ft (avg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>East</td>
<td>100</td>
<td>97.2</td>
<td>3.4</td>
<td>315</td>
<td>121.5</td>
<td>86.1</td>
<td>86.1</td>
</tr>
<tr>
<td>West</td>
<td>53</td>
<td>86.4</td>
<td>3.0</td>
<td>357</td>
<td>81.5</td>
<td>3.0</td>
<td></td>
</tr>
</tbody>
</table>

Tree height was measured by experienced University of Minnesota forestry scientists, Bernie McMahon and Tom Levar on October 10, 2007 (Fig. 14). At each measurement plot location the heights of 10 trees were measured as height in cm, then converted to height in feet for reporting. If less than 10 trees were available in the row plot, then trees closest to the missing trees in adjacent rows were measured. Table 3 shows that the overall average tree height in the east field was 3.8 ft and in the west field was 2.9 ft. The variation in height among trees was very high in both fields with the standard deviation around the mean being 1.5 and 1.4 in the east and west fields respectively. Some sections of each field showed better growth and less variation as demonstrated by individual plot (10 tree) mean heights, which ranged from 1.3 ft to 5.6 ft in the east field and 0.8 ft to 5 ft in the west field. The shortest live tree measured within the sampled areas was 0.3 ft in an area of very poor soil and the tallest individual tree measured was 6.8 ft in height in an area of good soil (Figs. 15, 16). Due to the large number of trees measured, the confidence level in the mean value was within 0.1 ft in both fields, and statistical comparisons of the total field mean heights demonstrated a significant statistical difference (at the 95% confidence level) in height between the east and west fields.

Table 4 shows a comparison of trees that were chlorotic versus trees that were not chlorotic. The results show an average difference in height of 0.8 ft in the east field but no difference in the west field. Both chlorotic and non-chlorotic trees showed great variation in height with some of the “runts” having very green leaves and others being chlorotic (Figs. 17, 18). An interesting observation was that none of the trees in the east side of the west field (a heavy weed area that did not receive post-planting herbicide applications) were chlorotic (Figs. 19 & 20).

Glencoe Site Monitoring

On May 20, 2007, EPS reviewed the 2006 planting site for 2nd year survival and general health. Several areas’ trees (<1 acre) seemed to have died due to soil toxicity or high PH when checked in late 2006 during our plots sampling. Surprisingly, the 2007 inspection found them growing vigorously with few or
no signs of chlorosis. Upon close examination, it was found that the plants were sending out two or more new branches near the ground with the tops having died back. This was not a result of winter kill as would normally be the prognosis if the site had not been inspected during the previous year’s late growing season which revealed them defoliated and dried up.

![Survival of tree slips that previously had been consider dead](image)

It is not known how these trees could have survived except that the roots were not completely destroyed. One possibility is that the roots were able to grow through the toxic/high PH layer in early spring and provide the above ground stem with the proper nutrient levels such as usable iron and manganese.

As a result of the second year monitoring, two valuable pieces of information were obtained: First, a re-plant determination of an area that appears to have been lost to severe iron chlorosis, should not be made until early summer of the second growing season. Second, soil chemistry and its affect on tree health is likely biased by other conditions such climate. It is known that soil moisture has a significant affect on available plant nutrients and can vary the concentrations of available nutrients, unwanted salts and PH levels.

**Discussion and Conclusions.**

The density of trees at the end of the first growing season resulted from a combination of factors. In the hand planted area, the initial planting density in the west field was less than expected largely because the field was not cross-checked before planting, thus planting location was based on the estimation of density made by the hand planters. Distances between trees varied from row to row in the hand planted area – possibly depending upon the stride of each individual planter. This was not accounted for directly in the measurement (since a plot of 10 trees was always selected) but an adjustment was made based on the evaluation made in July 2007 that trees in the hand planted area were spaced at approximately 5 ft x 5.3 ft, thus being 6% less dense than a 5 ft x 5 ft spacing. In the machine planted area, “skips” in placement of the cuttings resulted from inexperience with the new planter and the many stops and starts that occurred as adjustments were made to the planter and as the crew gained experience with the GPS guidance system on the planter. In the machine planted and hand planted areas, another factor affecting final density was the quality of the cuttings. As discussed in Milestone report 12, many of the cuttings did not meet the minimum size specification, and thus were likely unable to withstand the drought stress. During the
process of measurement, it was noted that trees that were dead either had the initial cutting sticking high
out of the ground and/or the initial cutting size was very small. Often the two factors were associated.

The results show that height growth was excellent in some parts of each field and very poor in other
sections. At this time, the data do not allow us to fully interpret the causes for the variation in growth
between areas of each field, or to explain the differences in mean heights between the two fields, largely
because there are so many interacting variables. These variables include, time of planting, nature of
planting (hand vs. machine), size of cuttings, condition of the cuttings at time of planting, micro-field soil
type and pH differences, differences in weed control effectiveness, and differences in timing of mowing in
different sections of the field. Variables of this nature are a normal circumstance when planting at a
commercial scale at the same time that new equipment is being tested. It is likely that soils variations are
a major factor, but soil testing has not yet been performed. Soil testing plots will be established next
spring to specifically look for correlations between areas of the field with excellent growth, versus areas
with poor growth. These areas can be somewhat distinguished in the aerial photos with the greenest areas
showing the best growth and areas that are brown, tan or grey showing poorer growth.

Trees that had yellow leaves at the time of measurement on October, 10, were presumed to be suffering
from chlorosis (a condition where the iron uptake is not adequate for supporting good plant growth).
Their appeared to be a negative effect of chlorosis on growth in the east field but no effect in the west
field. This will need to be followed up with observations in future years. It may be that some of the
chlorosis only showed up late in the growth season and thus had little effect on the growth.

Some differences in growth may remain a mystery. One example is an area six trees wide with high weed
growth, but also excellent tree growth. This area is most visible at the northern end of the west field (Fig.
19). This area may also be identifiable in the aerial view of the west field as a green strip - see Fig. 20.
These six rows are in the machine planted area and likely represent one pass of the planter. A possible
explanation is that the better growth section was machine planted in the morning with cuttings that were
fresh from the freezer (thus still very moist), and/or with a batch of cuttings that were larger in size than
many of the others. This explanation can not be verified, however.

The conclusions that can be drawn at this point are the following:
1) Overall growth and survival was excellent given the very droughty conditions that occurred
   following planting.
2) Tree growth and survival can be just as good when planted by machine as when planted by hand.
3) Tree growth and survival is reduced in areas with very high grass competition.
4) Tree growth and survival is very variable in areas with mostly broad-leaved weeds – thus it is
   likely that soil pH, other soil factors, and initial cutting size are the key variables.
5) Initial cutting size does make a difference with respect to being damaged while being planted and
   with respect to survival during the droughty period.

Future Tending, Monitoring, and Experimental Plans for the Graceville Site

Soil sampling will be done in spring 2008 at selected locations in order to determine the extent to which
plant growth can be linked to soil conditions. Locations will be selected with tall and short trees and with
high weed cover and low weed cover.
Weed control efforts will be started as early in 2008 as possible with a combination of herbicides and mowing.

If a significant portion of the field shows chlorotic conditions in the spring of 2008, consideration will be given to doing an experiment to determine if spraying the trees with iron and manganese chelates will supply the micronutrients needed for growth. This may at least be done on a small portion of the field as an experimental treatment.

In the fall of 2008 and each year thereafter, growth measurements will include diameter as well as height growth and estimates of biomass will be made.
Appendix A - Photos

Figure 1. Aerial view of farm landscape in the Graceville MN area.

Figure 2. The landowner, Dean Frisch (on right) was very interested and involved in the project and is shown here with the project leader, David Ostlie.
Figure 3. West field, aerial view from south.

Figure 4. Aerial view of the east field from the south.
Figure 5. Small strip missed by pre-plant spray applied in Mid-May 2007, shows that overall weed control was relatively good prior to planting.

Figure 6. A medium density of broad leaf weeds was the situation of the majority of the east field in mid-July.
Figure 7. Portion of east field showing strip of poor grass weed control on untilled ground (right) next to strip of relatively good weed control on tilled ground (left) in mid-July. The lack of rain was a major factor in this result.

Figure 8. Four foot high flags were used to identify location of tree rows in the non-herbicided area of the west field.
Figure 9. Relatively good tree growth occurred within the non-herbicided area through mid-July.

Figure 10. Section of west field after mowing between the trees in the north-south direction.
Figure 11. Plot locations overlaid on aerial view of east field.

Figure 12. Plot locations overlaid on aerial view of west field. The north-south distance appears shorter than it actually is due to the perspective from which the photo was taken.
Figure 13. The orange flag shows the east end of a measurement plot in an area of poor growth and heavy weeds.

Figure 14. Bernie McMahon and Tom Levar measuring trees in an area of average tree growth, Graceville MN, October 10, 2007.
Figure 15. An area of excellent tree growth in the west field.

Figure 16. Co-investigator, Lynn Wright, standing in an area of excellent tree growth, is 5’3” tall thus the tree is over 7’.

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Figure 17. An area showing some chlorosis but average tree growth.

Figure 18. An area showing chlorosis and highly variable tree growth.
Figure 19. Six rows of good growth in the middle of the non-herbiced area. The light brown grassy area on the right was an area that did receive post-planting herbicides but which was never tilled.

Figure 20. The area in the north section of west field corresponds to the better growth area, shown in Figure 19.