Energy Performance Systems, Inc.

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

Contract Number: RD-50, Milestone Number: **8** Report Date: 1/16/07

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Congressional District: 4 (Corporate office: Rogers, MN)
Congressional District: 7 (Project Farm location: Glencoe, MN)
Congressional District: 6 (Equipment Building Location: Big Lake, MN)

MILESTONE 8a&b - SUMMARY REPORT (PUBLIC)

Post-Planting Tending and Monitoring and Spray Rig Modification

Executive Summary:

The first year of tending and growth of the hybrid poplars planted in Glencoe (Milestone 8a), Minnesota is well documented with photos and data. Support for collection of survival and growth data was provided by woody crop researchers located at the University of Minnesota's Natural Resources Research Institute in Duluth, MN. Survival was excellent overall, with only 3 % mortality. Growth was quite variable across the site, with some portions of the plantation containing trees that are 8-9 feet in height, and other portions of the site having trees only 2-3 feet in height. The average tree height across 30 plots on the site was 4.3 feet. Some portions of the site suffered from chlorosis, identified by a yellowing of the leaves and reduced photosynthesis. Several soil samples were taken in an attempt to identify the cause of the yellowing. More soil sampling will be needed to obtain a clear diagnosis. The hybrid poplar planting was tended using normal commercial procedures to the extent possible except that more effort was required for weed control than is normally practiced commercially on previously cropped land. Several years of "organic" management (which entailed no application of chemical herbicides) had left the site with a high weed seed population Mid-summer mowing of the site prevented the weeds from over-topping the trees on most of the site except for a couple of areas of solid stands of foxtail. In the final analysis, it appears that soil chemistry was more important than weeds (moisture and nutrient competition) in determining first year survival and growth. This is likely due to adequate rains and the high organic matter and water holding capacity of the soils in the Glencoe areas. For Milestone 8b, Spray Rig Modification, a spray rig was selected for modification and conceptual design work for the modifications completed.

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Technical Progress Milestone 8a

It should be noted that the planting and tending approach used on this field differs from most hybrid poplar management approaches in Minnesota in three ways. These differences are a critical part of the experimental aspect of the project, because if they are successful, they will result in rapid production of a harvestable crop at lower costs and with a more ecologically sound approach than is generally used in Minnesota. The differences are as follows:

1) The Glencoe site was not tilled prior to planting (except 3 strips that were lightly tilled for experimental comparison). Most hybrid poplars in Minnesota have been planted into tilled soil.
2) The trees were planted at a spacing density deemed most suitable for biomass energy (5 x 5 ft); most commercial pulpwood plantings are planted at 8 x 8 ft to 12 x 12 ft.
3) The site selected had very productive soils for corn and soybeans but the soils are heavier, with higher organic and slightly higher pH levels than is normally recommended for poplars. Most commercial hybrid poplars in Minnesota are planted on lighter soils a little further north and west of the Glencoe area.

<u>Post-planting Tending and Monitoring Activity on the Glencoe Experiment Site:</u>
Planting of 62 acres (over 100,000 hybrid trees) was finalized on Saturday June 17, 2006. The condition of the hybrid poplar cuttings at time of planting was excellent. A rainfall that occurred on June 16 provided an excellent level of soil moisture for giving the trees (and weeds) excellent conditions for growth. The first cuttings planted were already beginning to break bud by Sunday June 18th (Photo 1 – Appendix A). Previous applications of glyphosate herbicide appeared to have mostly killed weeds that had already emerged. The importance of the pre-planting, glyphosate applications are shown by a strip accidentally left unsprayed (Photo 2 – Appendix A).

Post-planting tending began immediately afterwards with the application of herbicide sprays on Tuesday, June 20th. The post-planting sprays were a mixture of Scepter 70 DG applied at 2.8 oz/acre and Pendulum 3.3 EC applied at 3 quarts/acre. The rates of application were not the highest labeled rates, but were rates similar to, or higher than, rates commonly used on other poplar or cottonwood tree farms in Minnesota and in Mississippi. Decisions on the herbicide types and rates of application were made after consulting with commercial hybrid poplar tree crop managers, several university researchers and with researchers from herbicide companies (BASF, Dupont, and Valent). The post-plant herbicides appeared to be effective based on July 14 photos (3 and 4, Appendix A), taken ~ 4 weeks after planting.

A neighboring farmer was hired to monitor the site on a weekly or bi-weekly basis. The farmer was provided with a camera to take pictures of the site. Unfortunately due to operator error, many of the photos taken by the farmer did not come out. However, Principal Investigator, David Ostlie, visited the site 6 times over the July – September period and was able to document the status of growth of the trees and weeds with photos. All ground level photos referred to in the text are placed in Appendix A. Weeds appeared to be kept under control for only about 6 weeks. Photos taken in early August show growth well under way with varying levels of weed competition across the field and some obvious chlorosis (yellowing) of some of the plants Photos (5,6). Weed growth had suppressed tree growth, in areas of dense grass growth (Photo 7). The tilled area on the east side of the area planted to trees had lower weed competition all season (Photo 8).

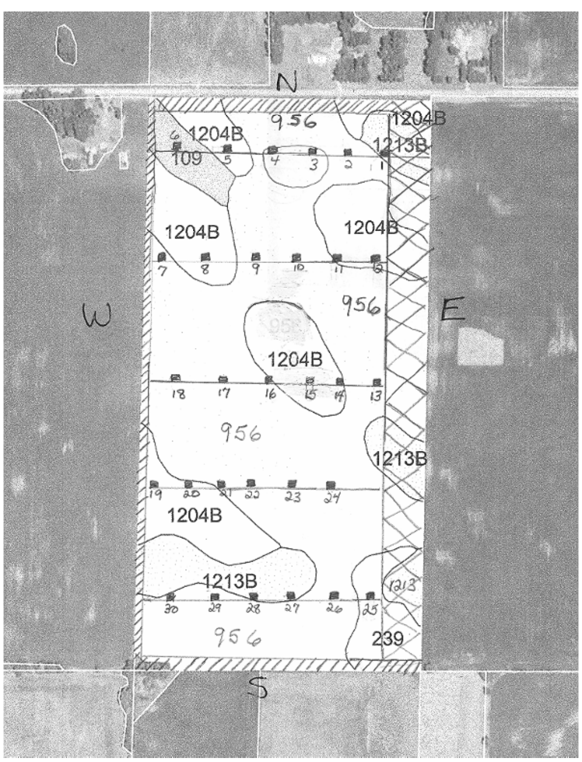
Because of the dense spacing, the only possible mid-season weed control approach available was to mow with a lawnmower small enough to get between the rows without damaging the trees. A small mower was purchased by the project, and local laborer was hired to do this job (Photo 9). The mowing was likely critical to reducing the weed competition on all portions of the site that were mowed. Weed competition was not the only factor affecting growth (Photo 10). After three good rains in late August and early September, growth of trees and weeds was good (Photo 11 and 12).

Tree measurement plots were established in late October and documented with photos. The plots were established on five linear transects across the field at approximately rows 40, 140, 240, 340 and 440, walking from the N to S end of field on the West side. The maximum number of E-W rows was 500 and the number of N-S rows was about 206. Within each transect, six plots were established beginning at least 4 trees from either the W or E edge. Each individual plot contained 25 trees. A total of 30 plots were planned for a total measurement sample of 750 trees across the 62 acres. Figure 1 shows the approximate location of the planted area and the measurement plots relative to the varied soil types on the site. A combination of photos on the ground at each plot, taped and hand written notes, and documented distances between plots were used to determine the location of each plot.

<u>Growth and Survival Results</u>

Growth was measured by experienced University of Minnesota forestry scientists on October 25, 2005 after first frost and all growth had ceased. The overall average height was 4.3 feet. Plot mean heights ranged from 2.0 feet to 6.6 feet. Individual tree heights ranged from ~ 1 foot in areas of very poor soil or extreme grass competition up to about 8 feet in height in the best soil areas. Survival was 96.6% in the measured growth plots.

Figure 1. USDA soils map with transects and plot layout. Transect 1 is at north end of the plot.



Predominant soil type descriptions are as follows:
956: Canisteo-Glencoe Complex – 61% of site; ~ 55% Canisteo and similar soils, ~ 30% Glencoe and similar soils, ~ 15% inclusions. Both are clay loam texture, very deep, with till parent material, high organic matter and slopes of 0-2%. Canisteo is poorly drained with seasonal high water table at 1-3 feet. Glencoe soils are very poorly drained with seasonal water table at 1 foot above to 1 foot below the surface and a very long ponding duration. **1204B:** Cokato loam – 23% of site; has a loam texture with high organic content. It is a very deep but well-drained soil with the seasonal high water table at a depth of more than 6 feet. **1213B**: Cokato-Storden Complex – 10% of site; ~ 55% Cokato and similar soils, ~ 30% Storden and similar soils. Slopes are 2-6 % on back slopes and shoulders. Both soils have a loam texture, are very deep and well-drained with a seasonal high water table at more than 6 feet. Organic content is high for Cokato but moderately low for Storden soil.

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Photo 1 – Aerial photo of the Glencoe hybrid poplar planting site taken late September, 2006.

This photo together with the soils map (figure 1) provides a lot of information about the variability in the field including soil types, tilled areas, and weed types and density. An interpretation of the varied colors on the field is given in Appendix B.

Analysis of Variability in Height Growth

Many factors affected the growth results on the site. The degree of variability on the site is visually shown by the aerial photo. Ground truth information on variations in elevation, slope, weed competition, weed type and tillage for each plot was derived from photos and notes. This was used to locate transects and plots on the aerial photo and to interpret the color variation seen in the photo. Analysis of the variables showed a strong relationship of height growth to elevation and soil type but only a weak relationship to weed competition (figures 2-5).

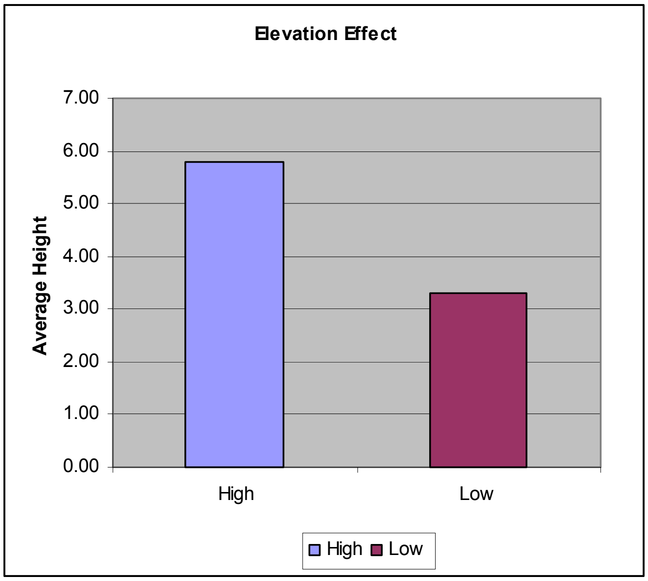


Figure 2. Average tree height on plots characterized as being on high or low areas of the field. Plots in the 'medium" elevation areas were not included.

Of the 10 plots in the low areas of the field, all produced height growth less than the mean value of 4.3 ft and several had height growth of < 3 ft. Of the 5 plots located in the highest areas of the field, all produced height growth above the mean value of 4.3 feet and 3 had heights > 6 ft.

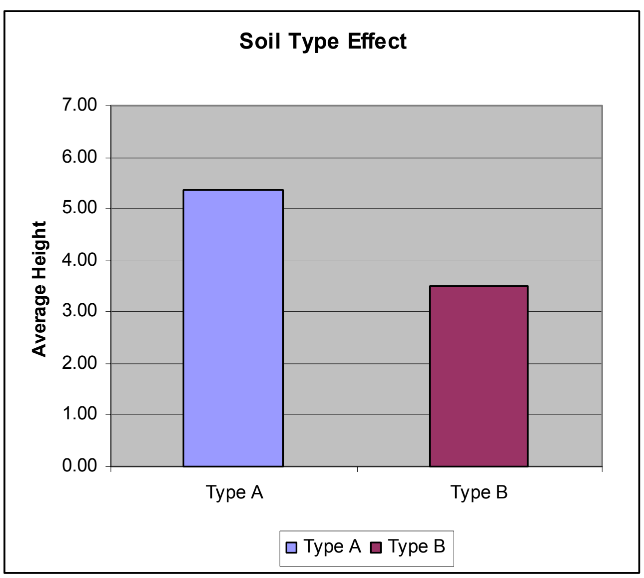
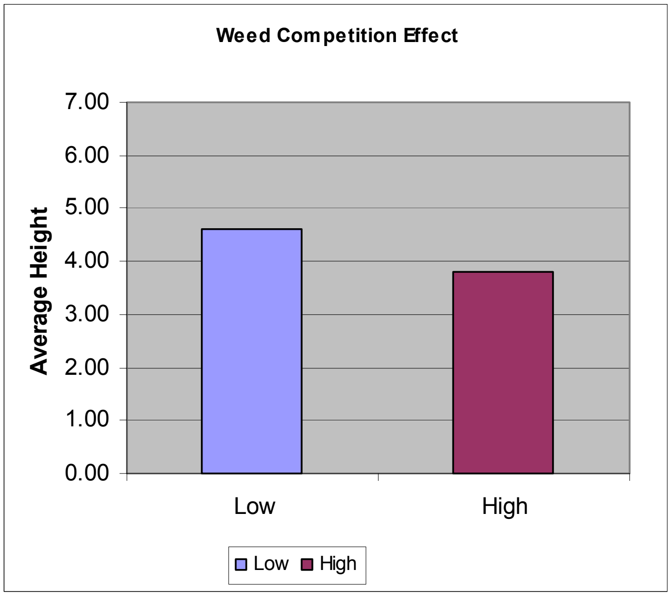


Figure 3. Soil type effects on height growth. Soil Type A was primarily Cokato Loam (1204B) but included 2 plots with Cokato-Storden complex soils (1213B). Soil Type B was the Canisteo-Glenco complex (956).

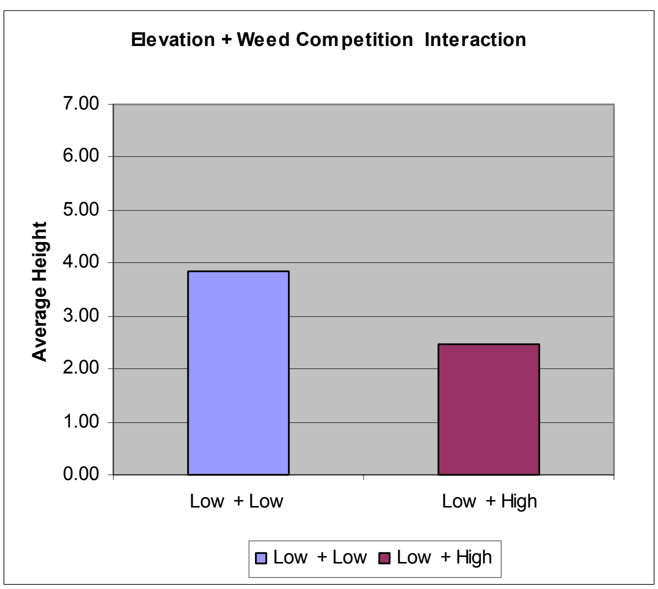
As can been seen by comparing the two plots there is a strong correlation between elevation and soil types. The 956 complex soils are clay loam soils found in depressions on moraines and the rims of those depressions. The 1204B and 1213B soils are loam soils found on "back slopes and shoulders". Soil type 956 is generally more alkaline than the 1204B and 1213B soils. Areas with yellow leaves (chlorosis) were also associated with the slopes or depressions in the field.

Figure 4. Assessment of yields in areas of low and high weed competition based on visual inspection in October.



The differences between high and low weed competition are not statistically significant as there was considerable variation. However weed competition was difficult to consistently rank. For instance, the very best growth plot on the field was also characterized as having high weed competition, but it may have been a case of tall weeds obscuring the view, rather than dense weeds competition. Areas of the field with dense weed growth were brown or tan in the aerial photo. All plots in areas characterized as brown were associated with height growth of < 4 ft, most were < 3 ft. There were no plots in "tan" areas on the aerial photo, but observations showed that survival was low and surviving trees were less than 3 feet in height. Thus high weed competition in combination with the poorer, lower elevation soils did appear to be a problem. This is evidenced by the results shown in Figure 5. There were insufficient examples of high weed competition in the high elevation areas to include for comparison. While it is our belief that soil type/elevation was more important than weed competition in determining growth results, it does appear that overall average growth might have been increased by one foot or more if the weed competition had been consistently reduced in the low lying areas.

Figure 5. Comparison of the effects of lower versus higher weed competition in the low lying areas.



The yellow (chlorotic) areas were insufficiently sampled relative to their extent in the field so it was not possible to perform an analytical comparison of the effects of chlorosis. However it was observed that of the 4 plots characterized as chlorotic, 3 had height growth < 3 ft; most chlorotic areas were in median or low elevation areas but a few were on knolls where soil sampling indicated high soluble salt levels. While chlorosis is generally associated with higher alkalinity areas, it was possible to find chlorotic and non-chlorotic trees in close proximity with the same pH levels in the soil. There was a difference in iron availability, nitrate-N levels, phosphorus levels, and "excess lime rate" in adjacent chlorotic and non-chlorotic areas. The areas with the green trees had the higher phosphorus level, higher iron availability, lower nitrate-N level and a lower excess lime level.

Discussion

Variation in the survival and height growth of the trees appeared to be primarily caused by variation in factors that we had little control over. That would include the differing elevations levels, soil types, and chemical composition of the soil related to soil type differences and previous management of the site. There was also a possibility of some herbicide toxicity. Fortunately rainfall levels appeared not to be a factor affecting growth due to the good water holding capacity of the soils on the site and good rains at planting and again in late August and early September.

Soils characteristics were likely the major factor determining growth results as well as the chlorosis or yellowing that appeared on some portion of the site. Soils analysis data provided by the land owner and collected prior to planting gave in inadequate representation of the site. That information suggested that pH was mostly 7.5 or below and no other factors presented any red flags. However soil sampling performed after tree growth began to show stress in some areas showed conclusively that chlorotic areas were associated with pH levels higher than 7.5 and low iron availability, plus higher soluble salts, and lower phosphorus than areas of green trees with good growth rates. We found it interesting that corn in an adjacent field was growing very well in soils that appeared to be creating problems for the poplar trees. Discussion with soil scientists suggested that soybeans would be more likely to have a similar chlorotic response as the trees.

Many experiments around the country have documented the negative effect of weed competition, particularly when moisture or nutrients are limiting or when weed growth quickly overtops tree growth. In this case, weed competition does not appear to have had a major effect on growth except in limited areas of the field – such as a couple of grass problem areas. By early September tree growth was very strong in weedy and non- weedy areas (photos 11 and 12). By late September, growth was absolutely excellent in some parts of the field (Photo 14). By late October, the tallest individual trees were close to feet tall (Photo 15).

The important question is whether information was gained from the weed control approach taken and the observed results. The herbicides used have been demonstrated to be appropriate at the rates of application in other areas in Minnesota. It is possible that due to the higher clay content of the soils on this site, a higher level of Pendulum, the grass herbicide, would have been warranted. Without specific experimentation, this cannot be known, but it was clear that grass was insufficiently controlled, particularly, in a couple of problem areas on the site. Given what we know now, we would be inclined to consider a higher initial application level of Pendulum and to follow-up with use of a back-pack sprayer in specific grass problem areas, if they are relatively small. There is a suspicion that some herbicide damage may have occurred on the far west side of the field. The cuttings in that area of the field were planted first and had been in the ground for 7 days before it was possible to get the post-plant herbicide applied. Given the warm mid-June temperatures and good rainfall, bud-break had already begun by the 4th day after planting (Photo 1).

Since the herbicides were effective on most areas of the field for about 6 weeks, the rainfall was probably sufficient to activate the herbicides, though it could have been marginal for the Scepter which requires enough rainfall to wet the soil to 2 inches depth within 7 days of application. The exact rainfall levels can not be known since much of the mid-summer rain occurs as a result of thunderstorm activity and can vary considerably within a few miles. However, following application of the herbicide, local rainfall records indicated that the only rainfall within 7 days was ½ to 1 inch within 5 days and no additional rain for another 20 days. Since rainfall is not within our control, it is risky to rely totally on herbicides for control, and we did not. The back-up approach was to hire a local laborer to mow between the rows. This probably would have been more effective, if project staff had been able to exercise enough oversight to assure that all areas of the field were mowed.

Most recommendations on hybrid poplar growth recommend tillage of the area before planting. Consequently, one of the embedded experiments on the field was the tillage of three strips in the field. The eastern most strip, ~ 100 ft wide, largely coincided with the unplanted area on the east side that also received a different herbicide (SureGuard). The only conclusion we can draw is that the combination of tillage and SureGuard did not control the weeds any better than SureGuard alone.

The second 100 foot wide strip did coincide with the beginning of the tree planted area on the east side of the field. From the aerial photograph, it is possible to link less weed competition to that tilled strip based on the amount of "gray" areas in the field. All four plots within that strip had higher than average height growth, but not the highest growth on the field. However, we know that some of the gray areas on the east side were associated with low areas that could not be planted to trees due to standing water at the time of planting. A third tilled area of smaller size (~ 30-50 ft wide) was not recognizable based on weed pressure by the end of the season.

It is our belief that tillage might have helped a little to reduce weed competition, but it also had drawbacks. For instance, it was very difficult to see the marker rows used to guide the (hand) planting after the rain in the tilled areas. Tillage requires an extra pass of the tractor over the field requiring more fossil use and labor cost.

Preliminary lessons learned

The first lesson was that aerial photographs are extremely valuable. In future experiments on large acreages, we would recommend getting aerial photographs at the beginning, middle and end of the season.

A second lesson would be to use all possible information to set up measurements plots in such a way that all of the variability in a field will be well represented. We would recommend using not only soil maps, but more detailed soil analysis as well as the aerial photographs.

A third lesson learned is to ask more questions about the site before renting and verify the answers. This may require speaking not only to the owner/manager of the field but local agricultural consultants and neighbors who might be familiar with how the site has been managed. This would help in deciding first whether to rent the site and secondly, how to improve the management of the site. For instance, while the weed growth situation may not have directly impacted the growth of the trees, it certainly created a poor impression regarding the management of the site. Better information might have helped us to improve that aspect of management of the site.

A fourth lesson learned may be to search for sites with a higher percentage of the higher elevation soil types associated with better drainage such as is represented on this site by the Cokato loam (1204B) and the Cokato-Glencoe complex (1213B) soils.

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For a fifth lesson, it would probably simplify the management requirements on the site if the majority of the soils have a pH less than 7.5 as is normally recommended. However, because the higher pH sites may be more readily available in Minnesota, we believe that this might not be a limiting factor in itself under two conditions. The first is that a more complete soil analysis of the site prior to planting might allow use of management techniques that would focus on balancing the micronutrients on the site. The second is that alternative clones with higher pH tolerance could potentially be planted on the sites. Such clones are available only in very limited amount since they have not yet been scaled up to adequate numbers for testing by local nurseries. Thus this second approach could not be implemented immediately.

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

To meet requirements of the county, trees within 50 feet of either side of the county drain tile will be killed with herbicide spray in the spring of 2007. This is to avoid any possible interference of the tree roots with the draining potential of the county tile.

Weed control efforts will be continued starting as early in 2007 as possible. Some experimentation with weed control approaches is planned. The field may be divided into strips with some strips receiving only mowing and alternate strips receiving an application of a combination of post-emergent and pre-emergent herbicides. The type of herbicides and type of spray equipment that can be used will depend on the relative rates of leaf-out of the trees versus the weeds. This will be closely watched and the spray options will be considered. Mowing will be a back-up approach for the areas receiving herbicide.

To better understand the effect of the soil types on growth of the hybrid poplar clone MN6 (the most widely planted clone in Minnesota), it may be necessary to have extensive soil sample data collected from many locations on the Glencoe field.

An effort will be made to obtain expert assistance in monitoring the nutrient status of the trees on the Glencoe site during the next 5 years using DRIS (diagnosis and recommendation integrated system) approach. This approach evaluates the balance among all nutrients based on norms for high yielding plantations (Coleman, 2006). It is not anticipated that nitrogen will be a limiting factor on the Glencoe site during the 5 year duration of the experiment due to the high nutrient status of the site resulting from several years of dairy cattle manure applications to the site. However the manures might be resulting in nutrient imbalances and micro-nutrients might be limited as evidenced by the chlorosis problem.

If the trees continue to exhibit chlorosis in the spring of 2007, experts will be hired to spray just the chlorotic areas of the field with iron and manganese chelates in an effort to supply the micronutrients needed for growth.

In the fall of the second year and each year thereafter, growth measurements will include diameter as well as height growth and estimates of biomass will be made.

Technical Progress – Milestone 8 b

The work on the modified spray rig was completed for milestone #8b. The work entailed completing a search for a self propelled spray rig that is trailerable in an assembled or ready-to-use condition. The spray rid chosen is the Melroe model 220 with 4 wheel suspension. The conceptual design modification for creating a 16-foot under-belly consists of adding hydraulicly actuated struts that will span 16 feet front to back and 16 feet side to side creating a 16 foot square foot print. The drive wheels will be chain driven whereas the front wheels will be free-wheeling and mounted on swivel struts to allow for turning. Drop nozzles will be added to the booms for spraying glyphosate below the leaf line of the trees. The actual modifications are to be completed as budgeted under milestone 12B.

Appendix A: Project Photos

Photo 1. June 17 2006. Showing buds beginning to break in cuttings planted on June 14, 2006. Post-planting herbicide application on June 20, 2006 could have potentially damaged some trees.

Photo 2. June 17, 2006. View from W to E showing a strip of field missed by the second glyphosate spraying, also shows low areas of field with water, morning after heavy rainfall.

Photo 3. July 14, 2006 – View of Glencoe field to NW from NE corner of tree planted area. Only one rainfall of < 1 inch had occurred since June 16, 2006 (mid-planting time).

Photo 4. July 14, 2006 – View of Glencoe field to SE taken from NE corner of planted area. Green areas in middle are grass spots not effectively controlled by herbicide.

Photo 5. August 5, 2006. View from N to S, showing chlorotic trees and relatively low weed competition from broadleaf weeds.

Photo 6. August 5, 2006. View from mid-field to NW showing heavy broadleaf weed competition.

Photo 7. August 5, 2006. Area of heavy grass, overtopping weeds. Area shows as tan in late September photo.

Photo 8. August 7, 2006. Some areas were showing green trees, reasonable growth and low weed competition. Rainfall had been only 4 - 5 inches in 53 days since planting, with 2-3 inches occurring only a week prior to this photo.

Photo 9. August 9, 2006. Example of mowing done to reduce weed competition.

Photo 10. August 9, 2006. Unexplained difference in tree growth between 2 rows.   Area to right may have unknown soil chemistry issues or herbicide toxicity.

Photo 11. September 4, 2006. Mid field view showing excellent growth in weedy area, area was probably mowed but weed and tree growth was good following 3 good rains in previous 3 weeks.)

Photo 12. September 4, 2006: (east side of field with showing area on left sprayed in June with SureGuard and areas on right that was till, sprayed a Scepter and Pendulum mix and mowed.)

Photo 13. September 20, 2006. East side of Glencoe site on North end showed some of the best growth. Lynn Wright, 5’2” in height standing next to a tree nearly 7 feet tall. The location is near Plot 1.

Photo 15. October 25, 2006. Greg Russell, a RC&D forester about 6 feet in height standing next to one of the tallest trees on the Glencoe site.

Appendix B. Description of Information Derived From Aerial Photos.

a) Rows of healthy trees are a grey-green color. Since bare soil is a gray color, it is somewhat difficult to discern the trees in areas with very few weeds, but given the 97% survival rate, there are trees in all rows but they may be small in some areas showing mostly grey.

b) The distinctly gray strip in the field on the east side (next to the unplanted area) corresponds to one of the areas that was tilled prior to planting. Most of the trees in this area were above average height except for a couple of locations where they were either not planted or stunted. Some of the gray strips on the west side can also be linked to tillage.

c) The areas of the field with the solid tree rows and dark green coloration (from weeds) are generally well drained, loamy soils (1204B -Cokato loam and 1213B Cokato-Storden complex). It appears that these areas also have pH in 6.5-7.5 range. Plots in these areas, showed the best growth and the weeds also grew very well, increasing the amount of green color.

d) The areas of the field with brown or tan colors, are lower elevation areas of the field, generally associated with more alkaline soils in the Canistee-Glencoe complex (area 956 on the soil map). The trees competed relatively well in most areas of brown coloration but could not compete at all in the areas with tan coloration, which are covered with a solid mass of a grass. Mowing likely aided in reducing competition in the brown weed areas during August and early September.

e) The trees rows with yellow reflectance (due to chlorosis) are generally associated with slopes and lower elevation areas of the field, usually surrounded by brown weeds. The trees were chlorotic, possibly due to the inability to uptake sufficient iron, but other micro-nutrients such as magnesium, zinc, and copper may be inadequately supplied to the plant as well.

f) Within the brown colored areas are some small patches of bright green weeds surrounding chlorotic trees, these are the lowest elevation areas in the field. One of those areas shows several spots of freshly dug black soil, where digging was being done at the time the photos were taken, to precisely locate the county drain tile. Trees within 50 feet of the drain tile will be harvested and sprayed with herbicide in spring 2007.

g) The grey/tan strip on the east side of the field was purposely left for experimentation with tilling, alternate herbicides, and for later planting with the machine planter. The herbicide (SureGuard), which was tested in that area of the field, controlled broadleaves reasonably well, but allowed a number of grasses to thrive.