

Short-Rotation Woody Crops Program

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Alternative Methods of Site Preparation for Short-Rotation Willow and Poplar Biomass Crops

Interim Report

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Executive Summary

The proper application of effective site preparation techniques is essential to the biological and economic success of short-rotation willow and poplar biomass crops. Failure to control weeds during site preparation and through the establishment year causes decreased survival and production, frequently resulting in the failure of the crop. The standard technique is fall tillage site preparation, which includes a late summer application of post-emergence herbicides, followed by plowing and disking before winter. A final cultivation is conducted the following spring, immediately prior to planting, which is followed immediately with the application of a pre-emergent herbicide.

While the fall tillage site preparation approach is effective for establishing willow and poplar biomass crops, it creates the potential for significant soil erosion. If conducted properly, the fall tillage technique results in limited vegetation cover from the time of plowing until the canopy begins to close in the summer of the second year of growth. Under these conditions soil erosion rates on sites with certain soil and topographic characteristics could exceed those recorded for annual agricultural crops. The majority of land that will initially become available for willow and poplar biomass crop production in the northeastern and midwestern United States is lower quality agricultural land that has characteristics that make it prone to soil erosion. In one study White et al. (1991) estimated that about 130 MT ha⁻¹ of soil were lost during the establishment year in a hybrid poplar trial on a Mardin silt loam soil with a 13% slope. The soil erosion issue is important because of the increasing concern surrounding non-point source pollution from agriculture lands, the detrimental effect it could have on long-term sustainability of the production system, and the damaging impact it could have on the public perception of willow and poplar biomass crops.

A variety of conservation tillage and other ground cover management techniques have been developed to address soil erosion concerns without adversely effecting crop yields for annual agriculture and orchard systems. Some of the more successful approaches include no-till and strip tillage. In addition, the use of cover crops and altering the timing of different tillage operations has been shown to reduce soil erosion. However, little work has been done on establishing short-rotation woody crops (SRWC) using any conservation tillage and/or alternative ground cover management techniques especially for systems with densities greater than 10,000 plants ha⁻¹.

This study assessed the impact of six different methods of site preparation on survival and aboveground biomass production of high density, short-rotation willow and poplar biomass crops. The six treatments studied were 1) the standard fall tillage system, 2) fall tillage followed by the establishment of a winter rye cover crop, 3) no-till, 4) strip tillage applied in the spring, 5) spring tillage, and 6) no weed control. The study site, located in Lafayette, NY, is a Honeoye silt loam soil with 2- 8% slope. It had been out of corn production for two years and was dominated by a mixture of perennial weeds. Following the application of the different treatments, plots were hand planted in the spring of 1997 with either willow (SV1 – *Salix dasyclados*) or hybrid poplar (NM6 – *Populus nigra x maximowiczii*) at a density of 14,376 plants ha⁻¹. The plants were coppiced during the dormant season after the establishment year. First rotation harvest occurred three years after coppicing.

Survival was assessed at the end of each growing season. After the establishment year and at the end of the first three-year rotation aboveground biomass production was measured directly by cutting the plants. Aboveground biomass

production was estimated in the first and second year of coppice growth using stem diameter measurements and allometric equations that had been developed previously.

Establishment year (1997) survival for the poplar was greater than 96% in five of the six treatments and 84% in the no weed control treatment. Poplar survival decreased by less than 7% in any treatment between the establishment year (1997) and the end of the first three-year rotation in 2000. Only the no weed control treatment had a significant reduction in survival. Willow survival at the end of the establishment year was good, ranging from 84 to 95%. By the end of the first rotation willow survival had dropped significantly in the no-till, no weed control and strip tillage treatments resulting in 30%, 55%, and 70% survival, respectively. Survival for the spring tillage, fall, and cover crop treatments at the end of the first rotation was 94%, 90%, and 85%, respectively.

At the end of the first three-year rotation, aboveground biomass production for poplar clone NM6 in the four best treatments (strip tillage, fall tillage, spring tillage, and cover crop) was 36.4 to 37.6 odt ha⁻¹. These are the highest reported first-rotation yields of NM6 grown at this density in the northeastern United States. Not controlling weeds reduced the poplar yield by 23.1 odt ha⁻¹. Treatments that included tillage increased production by 8.4 odt ha⁻¹ compared to the no-till plots.

At the end of the first three-year rotation willow clone SV1 aboveground biomass ranged from 0.4 odt ha⁻¹ in the no-till and no weed control plots to 24.0 odt ha⁻¹ in the spring tillage plots. The best production at this site was at the low end of the range of other trials in the northeastern United States where willow clone SV1 has been grown at this density. Biomass production was 13.2 odt ha⁻¹ greater in the weed control treatments compared to the no weed control treatment. Treatments that included tillage produced 16.9 odt ha⁻¹ more aboveground biomass than the no-till treatment. At the end of the first rotation the cover crop and spring tillage treatments produced 7.6 odt ha⁻¹ and 10.0 odt ha⁻¹ more biomass than the fall tillage treatment.

First rotation results from this trial indicate that the spring tillage, cover crop, or strip tillage treatments are viable alternatives to the currently standard fall tillage treatment for NM6 on similar sites. All of these treatments produced over 36 odt ha⁻¹ in the first rotation. These alternative site preparation approaches should reduce erosion potential on many sites by providing vegetative cover on the soil over a longer period compared to the standard fall tillage approach. Alternative site preparation treatments often produce different results depending on the field history, soil characteristics and weather conditions. Caution should be used when transferring these results to sites with field histories and soil characteristics that are different from the one used in this study.

For willow clone SV1 the spring tillage and cover crop treatments produced the most aboveground biomass followed by the fall tillage treatment. These approaches may be viable alternatives to the standard fall tillage approach to site preparation. However, first rotation production for the spring tillage and cover crop treatments was only 24 and 21 odt ha⁻¹ respectively. These values are at the low end of the range of values that have been reported for other trials in central NY using SV1 grown at a similar density. It is unclear at this point why the fall tillage treatment, which is currently the standard practice, was less successful than the spring tillage and cover crop treatment. Additional analysis of soil and foliar nutrient characteristics and levels of weed competition may help explain some of the differences between the treatments and the low overall production of SV1 in the first rotation. As with the poplar results, caution should be used when transferring these results to sites with field histories and soil characteristics that are different from the one used in this study.

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Introduction and Objectives

Regional energy shortages, dependence on foreign fossil fuel supplies, international efforts to reduce the level of CO₂ emissions, stricter NO_x and SO_x emission regulations, and declining economic viability of traditional agricultural systems have prompted the study and deployment of short-rotation woody crops (SRWC) for bioenergy and bioproducts in several countries. Over 16,000 ha of willow biomass crops have already been established in Sweden (Verwijst 2000). In the United Kingdom an eight MW gasifier that will be fueled primarily by short-rotation willow coppice is due to come on line in 2002. Several other countries, including the United States, have ongoing research and demonstration projects with SRWC underway.

Experimental yields of short-rotation willow in Sweden have ranged from 10 to 12 odt ha⁻¹yr⁻¹, which is the equivalent of four to five m³ (0.6 – 0.8 standard barrels) of oil. Peak production of to 30 odt ha⁻¹yr⁻¹ has been obtained in irrigated and fertilized plots (Christersson et al. 1993). Commercial yields have been considerably lower, about four odt ha⁻¹yr⁻¹, across almost 2,000 ha harvested over three years (Larsson et al. 1998). Poor establishment, the use of unimproved clones, ineffective weed control and improper nutrient management have all contributed to these low yields. Larson et al. (1998) predict commercial yields in the future should be around 7.5 odt ha⁻¹yr⁻¹ if these issues are addressed according to current management recommendations.

The willow biomass system being developed in New York State is based on years of research and operational experience in the United States, Canada, Sweden and the United Kingdom. The system consists of a double-row planting of approximately 14,300 plants ha⁻¹, following agricultural type site preparation using a combination of mechanical and chemical weed control. The plants are cutback (coppiced) following the first year of growth, which promotes multiple sprouting and rapid site occupancy, and then harvested on a three to four year coppice cycle. Nitrogen fertilizer is applied to the site after cutback and following each harvest (Volk et al. 1999). Experimental willow biomass crops in New York State have produced up to 27 odt ha⁻¹yr⁻¹ under irrigated and fertilized

conditions (Adegbidi et al. 2001). Commercial yields are expected to be in the range of 12 - 15 odt ha⁻¹ yr⁻¹ (Abrahamson et al. 1998).

The establishment phase, which lasts from the beginning of site preparation until the site is fully occupied, of SRWC is critical to both their economic and biological success. Establishment accounts for about 20 - 25% of total production costs for willow (Danfors et al. 1998, White et al. 1995). Survival rates at the end of the establishment year of less than 80% are considered unsuccessful (Bergkvist et al. 1996). Replanting is costly and can be ineffective since replanted cuttings are easily out competed by adjacent established plants (Verwijst 1996). Weed competition is the primary factor limiting the successful establishment of SRWC because willow and poplar are very susceptible to competition, especially for moisture. (Barkley 1983, Labrecque et al. 1994).

Alternative Methods of Site Preparation

Current site preparation recommendations for SRWC involve a combination of mechanical and chemical weed control (Boysen and Strobl 1991, Danfors et al. 1998, Volk et al. 1999) but vary depending on field history. The majority of sites in New York that have been used for willow biomass production were in hay, used for pasture, or fallow for one to three years prior to planting. Beginning site preparation in the late summer or early fall the year prior planting is the standard approach for these sites (Boysen and Strobl 1991, Danfors et al. 1998, Volk et al. 1999). If vegetation on the site is dense and tall, it is cut and allowed to regrow to a height of 15 – 25 cm. Post emergence herbicides are then applied when the vegetation is actively growing. Glyphosate is typically applied, but other post emergence herbicides or mixtures can be used as well. The choice of herbicides and their rates will depend on labeling guidelines, the vegetation present, and any local or regional restrictions. When the existing vegetation is clearly dead, the site is plowed to a depth of 25 cm or more and then cross disked. The next spring the site is disked followed by a pass with a cultipacker just before planting. Dormant hardwood cuttings are planted in the spring as soon as the site is accessible by agricultural equipment at a density of 14,300 cuttings ha⁻¹. Pre-emergent herbicides, typically oxyfloufen and/or simazine, are applied at the labeled rates over

the top of cuttings immediately after planting. If the application of pre-emergent herbicide is delayed so that buds are beginning to open, then the herbicides used should be chosen carefully since some pre-emergent herbicides can damage the plants after bud break (Wagner 2000). Additional mechanical or chemical weed control is applied during the first year if weed competition becomes severe enough to warrant it. The effectiveness of initiating site preparation the fall prior to planting is evidenced by survival rates greater than 80% and the rapid aboveground biomass production of the crop.

While the fall tillage site preparation approach is effective for establishing willow and poplar biomass crops, it creates the potential for significant soil erosion. If conducted properly, the fall tillage technique results in limited vegetation cover from the time of plowing until the canopy begins to close in the summer of the second year of growth. Under these conditions soil erosion rates on sites with certain soil and topographic characteristics could reach unacceptable levels. The majority of land that will initially become available for willow and poplar biomass crop production in the northeastern and midwestern United States is agricultural land that has characteristics that make it prone to soil erosion. Ranney and Mann (1994) reported that soil erosion rates up to $40 \text{ Mg ha}^{-1} \text{ yr}^{-1}$ could occur during establishment. In one study White et al. (1991) estimated that about 130 Mg ha^{-1} of soil were lost during the establishment year in a hybrid poplar trial on a Mardin silt loam soil with a 13% slope. The soil erosion issue is important because of the increasing concern surrounding non-point source pollution from agriculture lands (Welsh 1991), the detrimental effect it could have on long-term sustainability of the production system (Vance 2000), and the damaging impact it could have on the public perception of willow and poplar biomass crops.

Using the fall tillage site preparation system, the site is not fully covered with vegetation from the time of plowing until the canopy begins to close early in the beginning of the second growing season. During the first growing season canopy development is slow and a limited number of stems per plant are produced. Average leaf area for four willow clones in mid July and mid September respectively in the establishment year was 0.05 m^2 and 0.26 m^2 . Values for hybrid poplar clone NM6 at the same times were 0.18 m^2 and 0.92 m^2 (Tharakan 1999). At the end of the first growing season, the four willow clones

had an average of 2.2 stems per plant while NM6 had 1.6 stems per plant. As a result the site was not fully occupied during the first year. The current practice is to coppice the plants during the first dormant season so that multiple shoots are produced the next growing season, which contributes to rapid canopy cover. At the end of the first growing season following coppicing, the average number of stems on the four willow clones was 11.1 per plant while NM6 had 7.1 stems per plant. (Tharakan 1999). Average leaf area index of four willow clones was 0.98 m² by mid July of the first growing season after coppicing and peaked at 1.75 m² in mid September. Leaf area for poplar clone NM6 at the same time was 3.20 m² and 4.57 m² (Tharakan 1999). Cannell et al. (1988) and Chapman (1992) reported that leaf area index (LAI) is typically \geq one by late June or early July in the first growing season after coppice if weed control has been successful during the establishment year.

The easiest and most effective approach to reducing soil erosion on a site is to provide vegetative cover for the soil that will disperse rainfall energy (Hudson 1981). If SRWC could be established successfully, both economically and biologically, with some groundcover until the middle of the second growing season then erosion potential during the establishment phase could be reduced.

A variety of conservation tillage and other ground cover management techniques have been developed to address soil erosion concerns without adversely effecting crop yields for annual agriculture and orchard systems. Conservation tillage is any reduced tillage system that leaves >30% of the residue from the previous crop on the soil surface after planting (Lal et al. 1990). Some of the more successful approaches include no-till and strip tillage. In addition, the use of cover crops and altering the timing of different tillage operations has been shown to reduce soil erosion.

Little work has been done on establishing SRWC using any conservation tillage and/or alternative ground cover management techniques, especially for systems with greater than 10,000 plants ha⁻¹. Five different site preparation techniques, using a combination of mechanical and chemical weed control techniques, were tested on hybrid poplar (Hansen et al. 1984b). Treatments ranged from no-till preparation to using both post emergent and

pre-emergent herbicides and several tillage operations. They concluded that as the number of chemical and mechanical weed control operations increased both weed control, especially of rhizomatous species, and height growth were improved over two years. There was no treatment effect on survival. Eighteen different site preparation treatments including no weed control, no-till, various cover crops and pre-emergent herbicides were tested on high density willow and poplar plantings in the United Kingdom (Clay and Dixon 1996). Plots where ground cover – either weeds or cover crops – was not controlled until one to two months after establishment produced 30 – 50% less biomass than treatments where ground cover was controlled with pre-emergent herbicides. Following cutback weeds were aggressively controlled using post emergent herbicides. By the end of the first year of growth after cutback differences between the treatments had decreased. Clay and Dixon (1996) concluded that the willows and poplars have an ability to recover from weed competition in the establishment year. Therefore, allowing some undetermined level of ground cover in the first year may not have a detrimental effect on the first rotation yield of the planting.

The benefits of no-till site preparation methods in annual agricultural production systems include earlier access to the site in the spring, higher soil moisture in the plant root zone, reduced erosion, greater soil organic matter levels, elevated levels of soil nitrogen and exchangeable bases compared to cultivated soils, and reduced site preparation costs. Drawbacks of no-till methods include lower spring soil temperatures, increased weed populations, and increased soil bulk density (Lal et al. 1990). Reduced soil temperatures in the spring have been suggested as a factor reducing growth in hybrid poplar plantations (Hansen et al. 1986). Weeds, which can compete for moisture and nutrients, have been frequently identified as one of the most important factors limiting successful establishment of willow biomass crops (e.g. Danfors et al. 1998, Labrecque et al. 1994, Volk et al. 1999).

While the few studies that have tested no-till effects in SRWC have produced mixed results, the numerous benefits associated with no-till systems make them worth further testing. McKittrick (1990) compared no-till and complete tillage site preparation methods for the establishment of hybrid poplar with 1,111 plants ha⁻¹ on an alluvial silt loam. He

found that the total volume of clone DN-55 was similar on the no-till and cultivated plots after three years, despite the fact that no-till plots had a significantly lower survival rate. Dickman and Stuart (1983) noted that no-till approaches have been used to successfully establish hybrid poplar plantations, but do not cite specific data. In contrast, Hansen et al. (1986) found that height growth of two hybrid poplar clones established at 1,388 plants ha⁻¹ using conventional cultivation was 18 to 96% greater than sites prepared with no-till techniques. The difference was greatest on a poorly drained loam soil and smallest on an excessively drained sandy soil. No-till techniques resulted in higher moisture in the plant root zone and reduced soil temperatures in the spring. Hansen et al. (1986) suggested that these factors, especially reduced spring soil temperatures, would limit the usefulness of no-till practices for establishing hybrid poplar in northern latitudes. No-till plots of 14 clones of high density (15,300 plants ha⁻¹) willow established on an alluvial soil in northern New York produced between 3.4 – 9.2 odt ha⁻¹ yr⁻¹ in the first rotation. In the second rotation, production increased significantly to 7.30 - 19.8 odt ha⁻¹ yr⁻¹ (Volk et al. in press), with the best clones exceeding projected yields on sites established using fall site preparation techniques (Abrahamson et al. 1998)

Various ground cover management systems have been tested and developed for woody fruit crops to address concerns of potential soil erosion and long term sustainability of the systems. Welker and Glenn (1988) compared four systems (cultivated, herbicide, mowed sod, and killed sod) during the establishment phase of peach trees and found that the growth and fruit yield was greatest under the killed sod management system. This system included the establishment of a sod cover that was killed with herbicide prior to planting and left on the soil surface. The mowed sod treatment consistently had the lowest growth rates. Soil organic matter levels were higher under the killed sod treatment and there was a positive linear relationship between soil organic matter levels and tree growth after three years. Infiltration rates were four to eleven times greater under the killed sod compared to the other systems. In established vineyards Pool et al. (1990) found that over a four year period there was no differences in yield between various ground cover management systems, which included regular cultivation, permanent mowed sod cover and various herbicide treatments. They recommend the use of no-till management

systems in non irrigated vineyards because of the additional benefits of reduced soil erosion and compaction.

Maintaining strips of vegetation cover between established trees or vines has been tested in various agricultural and forestry systems. If strips are established along the contour then the length of the slope that water can flow is reduced, minimizing soil erosion. Welker and Glen (1989) found that peach tree cross sectional area growth was directly related to the vegetation free area maintained around the tree up to 9.0 m². Doubling the width of the vegetation free zone from 1.25 m to 2.5 m around apple trees did not affect the cross sectional growth or yield of apple trees (Merwin and Stiles 1994). Some studies have shown that later in the growing season apple tree roots concentrate under the untilled portion of the field where the soil moisture content is higher (Atkinson 1980).

The integration of cover crops into agricultural production systems has been developed to reduce runoff and soil erosion, and improve infiltration, soil moisture availability, nutrient availability, and weed control (Teasdale 1996). However, only a limited amount of work has been done on integrating cover crops during the establishment of perennial crops and trees. Living cover crops have been shown to compete strongly for water with a variety of trees and woody crops during establishment resulting in reduced growth (Cogliastro et al. 1990, Ferm et al. 1994, Hansen et al. 1984a, Malik et al. 2001, Merwin and Stiles 1994, Shribbs and Skroch 1986). Living cover crops have not been recommended in high density SRWC because of the potential for serious competition for moisture and possibly and light. A viable alternative, however, is to establish a cover crop in the fall after site preparation and kill it just prior to planting in the spring or establish a fall cover crop that produces a significant amount of biomass and then winter kills. This would provide groundcover during the late fall, winter and early spring prior to planting, which would reduce soil erosion during that time. If the cover crop is killed just prior to planting then a protective mulch could be left on the soil surface during the first growing season. This mulch has the potential to reduce erosion and weed growth while maintaining soil moisture and soil organic matter. This approach has been successful in vineyards (Pool et al. 1990) and orchards (Shribbs and Skroch 1986), and shown some potential in short-rotation sweetgum plantations (Malik et al. 2001). To date only a

limited amount of testing of this approach has been completed in high density SRWC plantations (Clay and Dixon 1996).

Objectives

This study examines alternative methods of site preparation and compares them to the standard complete fall tillage site preparation method. The objective for this study is to assess the effect of six different site preparation methods for short-rotation willow and hybrid poplar biomass crops on:

- (a) survival and aboveground biomass production,
- (b) soil physical and chemical properties
- (c) weed populations, and
- (d) willow and hybrid poplar foliar nutrient data

during the establishment year and the first three-year rotation.

Materials and Methods

Site Description

The study is located in Lafayette, NY on the High Meadows farm (48° 52' 42" N, 76° 06' 45" W), which is at an elevation of 298m (Figure 1). The soil is mapped as a Honeoye, which is a deep, well drained, silt loam soil, with a high available water capacity in the upper 60 – 90 cm that has formed on calcareous glacial till (Hutton and Rice 1977).

Methods

The study site was used for corn production in the summer of 1994 and was left fallow in 1995. Vegetation on the site was brush hogged once in late summer 1995. Site preparation for this trial began in August 1996 when vegetation on the site was mowed, baled and removed from the field. Glyphosate (2.25 kg ai ha⁻¹) was applied three weeks after the site was mowed. A two by eight factorial treatment using a randomized

complete block design was laid out using sixty-four plots that were 11.9 x 11.4 m in size (Figure 2).

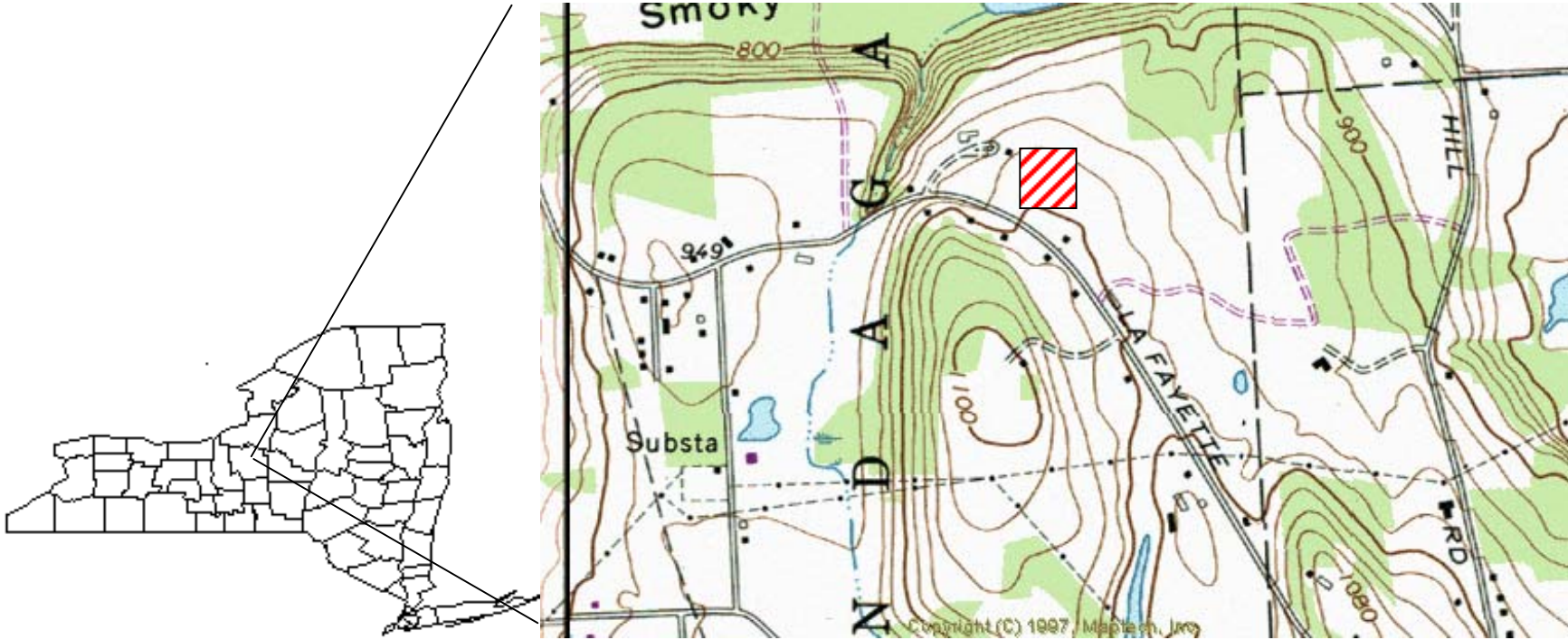


Figure 1. Location of alternative site preparation study for poplar (NM6) and willow (SV1) biomass crops in Lafayette, NY (Topographic map scale is 1:24,000).

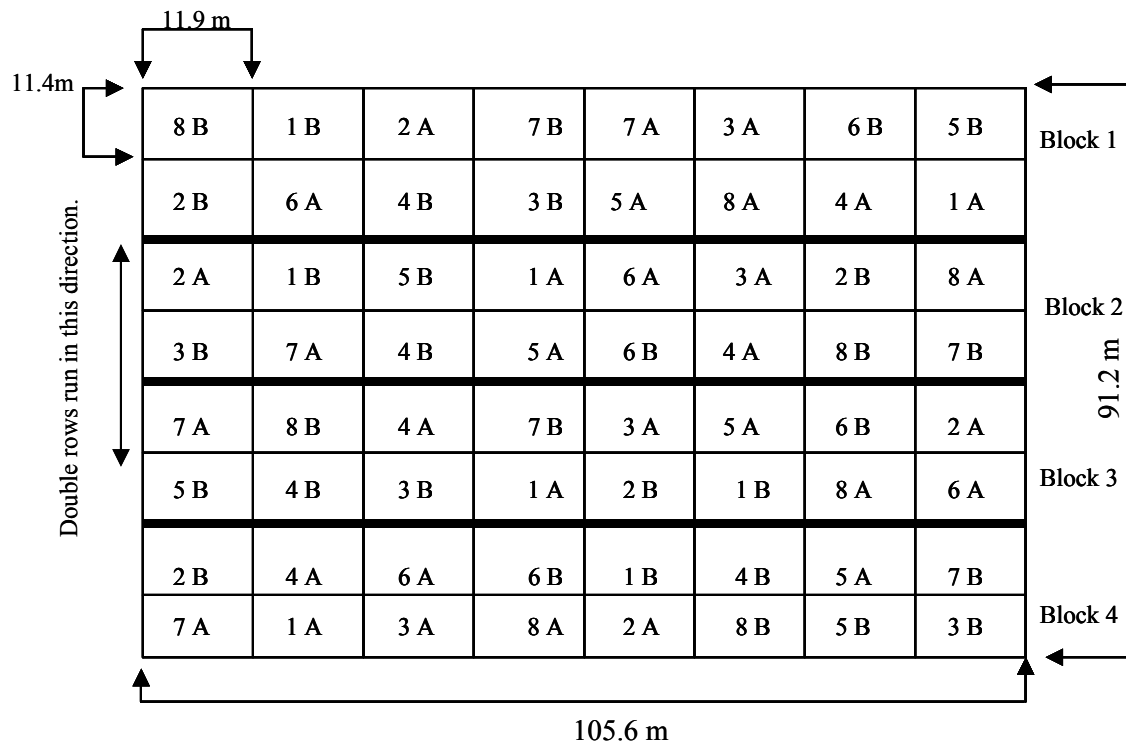


Figure 2. Layout of alternative site preparation treatments for poplar (NM6) and willow (SV1) biomass crops in Lafayette, NY. (Treatments are as follows: 1 - Fall till; 2 - Cover crop, 3 - No-till, 4 - Strip till, 5 - Spring till, 6 - No weed control, 7 - Machine planted fall till, 8 - Machine planted no-till. Plots one through six were hand planted. “A” plots were planted with willow clone SV1. “B” plots were planted with hybrid poplar clone NM6. (Diagram is not to scale).

Six different site preparation treatments (Table 1) were tested with two clones, one willow (SV1 - *Salix dasyclados*) and one hybrid poplar clone (NM6 - *Populus nigra x maximowiczii*). Out of the 240 plants established in each plot, measurements were taken on the middle 32 trees, resulting in buffer areas of 3.6 m (six plants) along the row and 4.4 m (four plants) across the rows (Figure 3).

The steps taken following the application of glyphosate in the fall of 1996 for the different site preparation treatments are outlined in Table 1. Moldboard plowing to a depth of 20 to 25 cm occurred on the appropriate plots 10-12 days after contact herbicide was applied, followed immediately by cross disking. Aroostook winter rye (*Secale cereale L.*) was planted the first week in October for the cover crop treatment with a

Brillion seeder at 124 kg ha⁻¹. Prior to planting in the spring of 1997 some perennial weeds were developing on the site so glyphosate (2% concentration) was spot sprayed on all but the no weed control treatment. Five to seven days after herbicide application, spring plowing and cross disking of the appropriate treatments occurred. Strips 1.2 m wide were rototilled in the strip tillage treatments. Dormant hardwood cuttings 25 cm in length were removed from frozen storage (-2°C) two days prior to planting and soaked in water. All the treatments were hand planted using dibbles at a density of 14,376 plants ha⁻¹ using a double row design. Two days after planting oxyflouofen (1.1 kg ai ha⁻¹) was applied on all but the no weed control plots. Spot applications of glyphosate (2% concentration) and hand weeding of plots was conducted during the establishment year and the beginning of the first year after cutback (spring 1998) to reduce weed competition on all but the no weed control plots.

Survival of the 32 trees in the measurement plots was assessed on December 5, 1997. All the plants were cutback on December 6 - 8 at between one and two centimeters height. The aboveground biomass of each plot was weighed, dried at 65° C to a constant dry weight and weighed again to determine moisture content and oven-dry aboveground biomass production. At the end of the first (1998) and second (1999) growing seasons after cutback, the diameter of all stems on each of the 32 surviving stools in the measurement plot was measured 30 cm above the soil and the maximum height of each stool was measured. The aboveground biomass was estimated for each plot using allometric equations developed by Ballard et al. (2000). At the end of the third (2000) growing season after cutback, the measurement plots were harvested after complete leaf fall, and aboveground biomass was measured. A subsample of one small, one medium, and one large stem per plot was selected and used to determine moisture content of the harvested material. Relative growth rates for aboveground biomass in the first, second and third year after coppice were calculated as follows:

$$\text{Relative growth rate} = \frac{(W_2 - W_1)}{W_1} * 100$$

Table 1. Timeline of field activities for six different site preparation treatments for poplar (NM6) and willow (SV1) biomass crops in Lafayette, NY.

Field Activity	Site Preparation Treatment					
	Fall tillage (1)	Cover crop (2)	No till (3)	Strip tillage (4)	Spring tillage (5)	No weed control (6)
Mow (summer 1996)	X	X	X	X	X	X
Post emergent herbicide (glyphosate at 2.25 kg ai ha ⁻¹) (summer 1996)	X	X	X	X	X	X
Moldboard Plow (fall 1996)	X	X				
Disk (fall 1996)	X	X				
Plant cover crop (fall 1996)		X				
Post emergent herbicide (glyphosate at 2% concentration) (Spring 1997)	X	X	X	X	X	
Plow (spring 1997)					X	
Disk (spring 1997)	X	X			X	
Rototill 1.2 m wide strip (spring 1997)				X		
Plant willow (SV1) and poplar (NM6) cuttings (spring 1997)	X	X	X	X	X	X
Pre emergent herbicide (oxyflourofen at 1.1 kg ai ha ⁻¹) (spring 1997)	X	X	X	X	X	

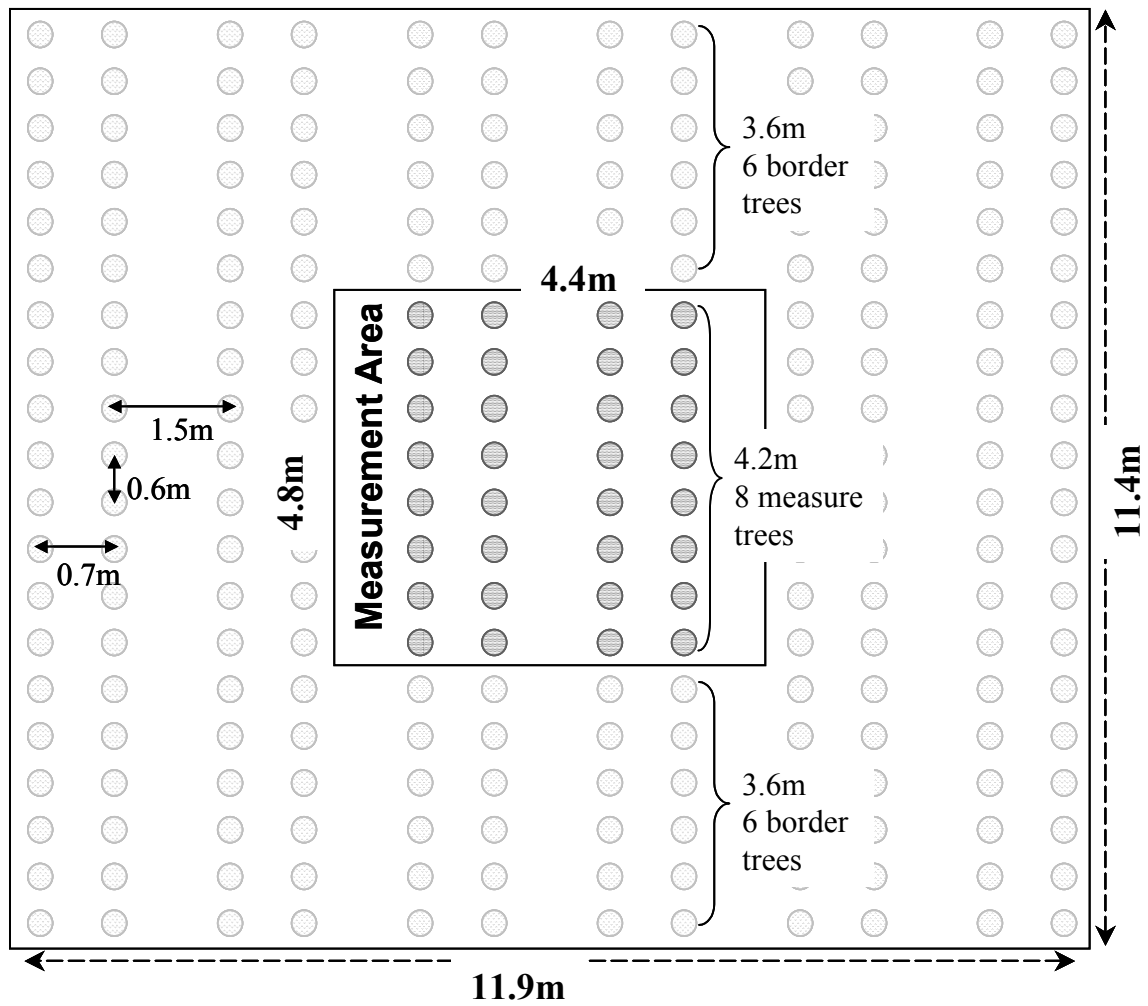


Figure 3. Layout of an individual plot in the alternative site preparation study for poplar (NM6) and willow (SV1) biomass crops in Lafayette, NY.

Soil samples were collected at two depths (0 - 10 and 10 - 20cm) at four points in each plot in May of 1997 and again in May of 2000. Soil organic matter was determined by loss on ignition. The macro-Kjeldhal method was used to determine nitrogen concentration. Potassium, calcium and magnesium were extracted with ammonium acetate (pH 7.0) and analyzed by atomic absorption spectrophotometry. Phosphorus was extracted with the Truog method and concentrations were determined using a spectrophotometer. Soil reaction (pH) was measured in a soil:water (1:2) solution (Bickelhaupt and White 1982).

Samples of mature, fully expanded leaves from the top third of the crown from plants in the buffer area in each plot were collected between August 15 and September 15 each year for nutrient analysis. Samples were dried at 65°C to a constant weight and ground in a Wiley mill to pass through a 2 mm screen. The macro-Kjeldahl method was used to determine N concentration. P concentration was determined using the ammonium molybdate vanadate method and a mass spectrometer. K, Ca and Mg concentrations were determined using the dry ashing procedure with 6 N HCl and atomic absorption spectroscopy (Bickelhaupt and White 1982).

Statistical Analysis

Analysis of variance was used to assess treatment effects on survival and biomass production using the following model with fixed effects. The data was analyzed as a completely randomized block design.

$$y_{ijk} = \mu + b_i + t_j + c_k + t^*c_{jk} + \varepsilon_{ijk}$$

Where:

y_{ijk} = i^{th} observation of the j^{th} treatment of the k^{th} clone

μ = overall mean of the observations

b_i = added effect of the i^{th} block

t_j = added effect of the t^{th} treatment

c_k = added effect of the c^{th} clone

t^*c_{jk} = interaction effect between the t^{th} treatment and the c^{th} clone

ε_{ijk} = random effect associated with the y_{ijk} , $\varepsilon_{ijk} \text{NID}(0, \sigma^2)$

Significance of hypothesis for the interaction effect was assessed at $\alpha = 0.20$. The following set of orthogonal linear contrasts were used to test simple effects for SV1 and NM6 separately when the interaction term was significant:

- a. weed control – no weed control: average of treatments 1 through 5 minus treatment 6 (see Table 1 for treatment numbers)
- b. tillage – no-till: average of treatments 1, 2, 4 and 5 minus treatment 3
- c. fall tillage – spring tillage: average of treatment 1 and 2 minus the average of treatment 4 and 5
- d. fall tillage – cover crop: treatment 1 minus treatment 2
- e. spring tillage – strip tillage: treatment 5 minus treatment 4

All statistical analysis was conducted using SAS (SAS 1999).

Results

Only survival and biomass production results are included in this interim report.

Survival

The interaction of plot treatment and species had an effect on survival in all four years with p-values of 0.1881, 0.0563, 0.0601, and 0.0008, respectively (Table 2). Linear contrasts for simple effects were examined for poplar and willow separately.

Hybrid Poplar - NM6

Establishment year (1997) survival for poplar was greater than 84% for all treatments (Figure 4), and greater than 96% in five of the six treatments. In the first year of growth after cutback, survival in the poplar plots dropped by 1.6 – 6.2%, with the largest decreases in the strip tillage and no weed control plots. The greatest change in hybrid poplar survival from the end of the establishment year (1997) until harvest in 2000 was 6.3% in the no weed control plots. A paired t-test indicated that none of the decreases in survival were significant at $\alpha = 0.05$ (Table 3). However, survival in the no weed control treatment was significantly lower in each of the four years compared to treatments with weed control (Table 4). There were no differences in poplar survival on the no-till plots

compared to the average of the tillage treatments in any year. Conducting tillage operations in the fall versus the spring did not have any effect on poplar survival.

Willow - SV1

Willow (SV1) survival at the end of the establishment year ranged from 84 to 95% (Figure 5). Willow survival dropped by 0 – 27.3% between the end of the establishment year and the end of the first year of coppice growth after cutback. The greatest decreases were in the no-till (27.3%) and no weed control (10.9%) treatments. Over the next two years willow survival continued to decline in the no-till, no weed control, and strip tillage treatments, so that by the fall of 2000 survival on these plots had dropped to 30.5%, 55.5% and 70.3%, respectively (Table 3). Not using tillage on this site significantly decreased the survival of the willow in the establishment year (Table 4). This difference was maintained throughout the first three-year rotation. Weed control did not significantly effect survival in the establishment year or the first year after coppice. However, the continual decline in survival in the no weed control treatment resulted in lower survival by the end of 1999 and 2000 compared to the treatments where weed control was applied.

By the end of the first rotation survival on the strip tillage treatment was significantly less than on the spring tillage plots. The application of complete tillage in the fall versus the spring did not effect survival over the four year period.

Table 2. Mean square and p-values from ANOVAs for survival over four years for six different site preparation treatments for poplar (NM6) and willow (SV1) biomass crops in Lafayette, NY.

Source	DF	<u>1997</u>		<u>1998</u>		<u>1999</u>		<u>2000</u>	
		Mean square	p-value	Mean square	p-value	Mean square	p-value	Mean square	p-value
Block	3	18.7174	0.6462	99.6147	0.4704	164.0869	0.4616	128.6936	0.5229
Treatment	5	108.3984	0.0174	583.0838	0.0015	1020.6264	0.0009	1594.6853	<0.001
Species	1	208.3333	0.0178	1104.0008	0.0040	3035.3102	0.0003	5088.2008	<0.001
Treatment x Species	5	53.5482	0.1881	279.7908	0.0563	443.3937	0.0601	933.7363	0.0008
Error	33	33.5138		115.5315		186.5173		168.6718	

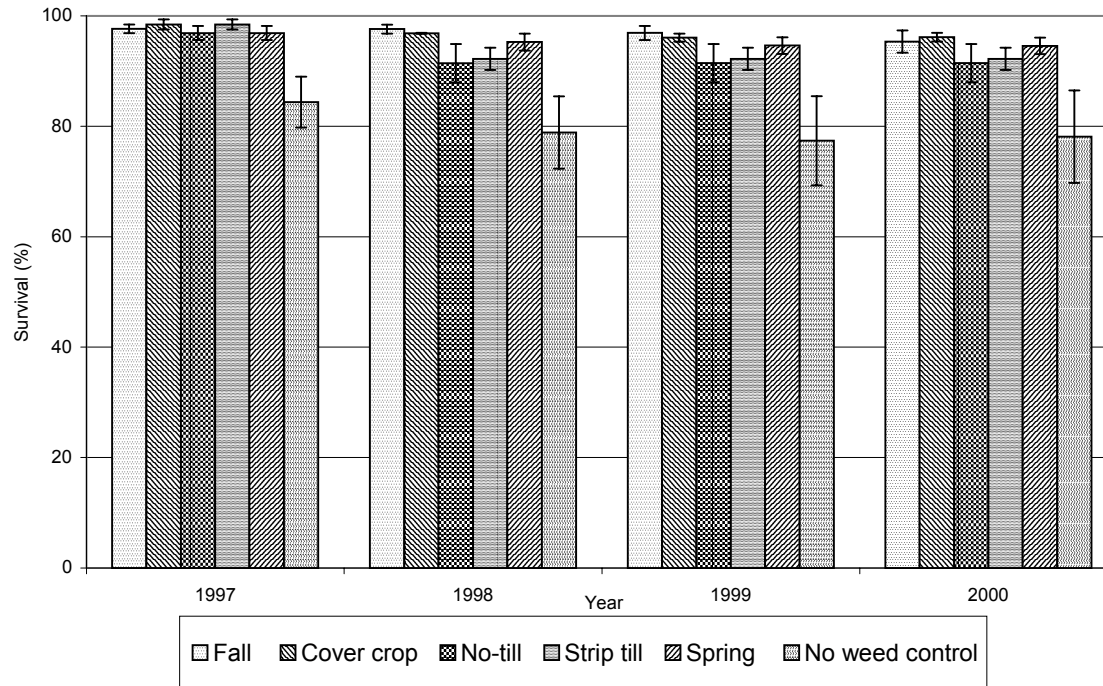


Figure 4. Survival (mean \pm standard error) of poplar (NM6) biomass crops in six different site preparation treatments over four years in Lafayette, NY.

Table 3. Changes in survival from the end of the establishment year (1997) through the end of the first rotation (2000) for six different site preparation treatments for poplar (NM6) and willow (SV1) biomass crops in Lafayette, NY.

Change in survival from 1997 to 2000			
Treatment	Mean	Standard error	p-value of paired T-test
Hybrid Poplar (NM6)			
Fall tillage	2.33	1.50	0.2186
Cover crop	2.31	1.49	0.2186
No tillage	5.45	2.34	0.1027
Strip tillage	6.23	2.56	0.0925
Spring tillage	2.33	1.49	0.2172
No weed control	6.25	4.43	0.2530
Willow (SV1)			
Fall tillage	4.71	0.91	0.0138
Cover crop	9.38	5.56	0.1901
No tillage	55.49	9.50	0.0100
Strip tillage	21.08	7.89	0.0756
Spring tillage	0.78	0.79	0.3910
No weed control	33.59	12.12	0.0695

Table 4. Linear contrasts and p-values for survival over four years for poplar (NM6) and willow (SV1) biomass crops for six different site preparation treatments in Lafayette, NY.

Linear contrast	<u>1997</u>		<u>1998</u>		<u>1999</u>		<u>2000</u>	
	Estimate (%)	p-value	Estimate (%)	p-value	Estimate (%)	p-value	Estimate (%)	p-value
Hybrid Poplar (NM6)								
Weed control – No weed control	13.3	0.0001	15.8	0.0106	16.8	0.0298	15.8	0.0310
Tillage – No tillage	1.0	0.7555	4.1	0.5002	3.5	0.6474	3.1	0.6660
(Fall tillage + Cover Crop) – Spring tillage	1.2	0.7330	2.0	0.7660	1.9	0.8182	1.2	0.8821
Fall tillage – Cover crop	- 0.8	0.8438	0.8	0.9189	0.9	0.9299	- 0.8	0.9303
Spring tillage – Strip tillage	- 1.6	0.6938	3.1	0.6889	2.4	0.8080	2.4	0.7973
Willow (SV1)								
Weed control – No weed control	2.8	0.3621	5.1	0.3884	15.5	0.0447	18.1	0.0143
Tillage – No tillage	7.4	0.0224	30.9	<0.0001	37.9	<0.0001	53.9	<0.0001
(Fall tillage + Cover Crop) – Spring tillage	0.4	0.9123	- 3.5	0.5921	- 5.5	0.5134	- 5.9	0.4600
Fall tillage – Cover crop	0.8	0.8438	2.4	0.7551	3.1	0.7467	5.4	0.5522
Spring tillage – Strip tillage	2.4	0.5532	10.2	0.1855	18.8	0.0586	22.7	0.0174

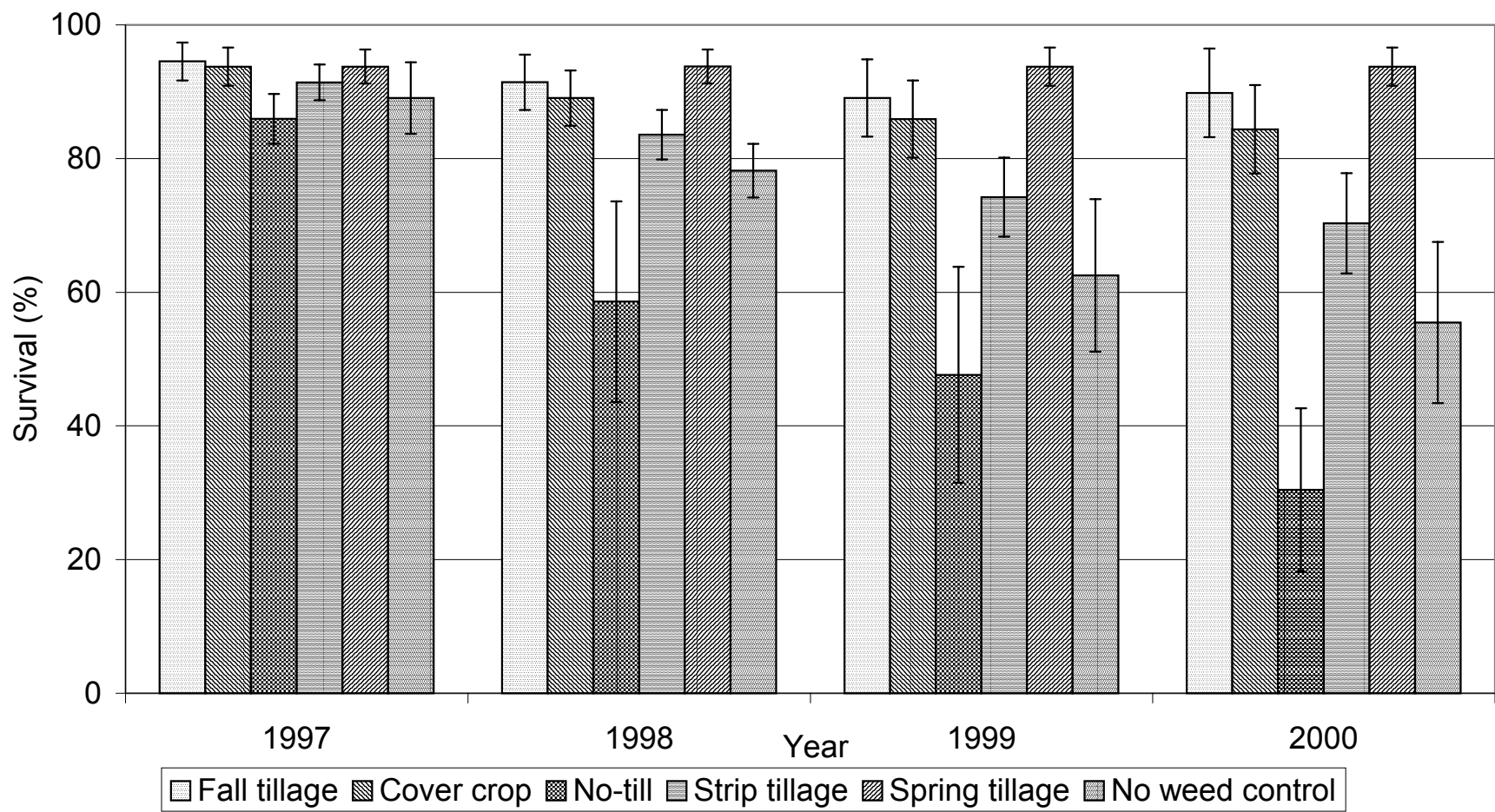


Figure 5. Survival (mean \pm standard error) of willow (SV1) biomass crops in six different site preparation treatments over four years in Lafayette, NY.

Biomass Production

For aboveground biomass, the interaction between the species and site preparation treatment was significant in all four years (Table 5). Simple effects for the willow and poplar aboveground biomass production were examined separately.

Hybrid Poplar – NM6

Site preparation treatments had an effect on hybrid poplar aboveground biomass in the establishment year when production ranged from 0.2 – 1.5 odt ha⁻¹ (Figure 6). The no weed control treatment produced 1.0 odt ha⁻¹ less biomass than the average of the weed control treatments (Table 6). Biomass production on the no-till treatment was 1.0 odt ha⁻¹ less than the average of the tilled treatments. Spring cultivated treatments produced 0.2 odt ha⁻¹ more biomass than the treatments that were tilled in the fall ($p = 0.0392$). The cover crop treatment produced 0.2 odt ha⁻¹ more biomass than the fall tillage treatment ($p = 0.0205$). The strip tillage treatment produced 0.36 odt ha⁻¹ less biomass than the full spring tillage treatment during the establishment year.

Estimated aboveground biomass production after the first and second year of coppice growth respectively ranged from 0.7 to 7.7 odt ha⁻¹ and 2.1 to 13.6 odt ha⁻¹. The no weed control treatment produced significantly less aboveground biomass in both years compared to plots with weed control. Tillage significantly increased aboveground biomass production in both years. Aboveground biomass production at the end of the first three-year rotation ranged from 12.0 odt ha⁻¹ in the no weed control treatment to 37.6 odt ha⁻¹ in the strip tillage treatment. The cover crop, fall tillage, and spring tillage treatments also produced more than 36 odt ha⁻¹ of aboveground biomass. The only significant differences in aboveground biomass production were between the weed control and no weed control treatments and the tillage and no-till treatments. By the end of the first

Table 5. Mean square and p-values from ANOVAs for aboveground biomass production over four years for poplar (NM6) and willow (SV1) biomass crops for six different site preparation treatments in Lafayette, NY.

Source	DF	<u>1997</u>		<u>1998</u>		<u>1999</u>		<u>2000</u>	
		Mean square	p-value	Mean square	p-value	Mean square	p-value	Mean square	p-value
Block	3	0.0214	0.2539	2.4559	0.2556	17.4133	0.0063	53.7507	0.0358
Treatment	5	0.7462	<0.0001	18.6152	<0.0001	80.5928	<0.0001	415.5402	<0.0001
Species	1	12.5679	<0.0001	272.9871	<0.0001	723.0769	<0.0001	1603.8344	<0.0001
Treatment x Species	5	0.6911	<0.0001	12.3686	0.0001	18.8793	0.0011	67.2574	0.0060
Error	33	0.015078		1.7346		3.5509		16.7838	

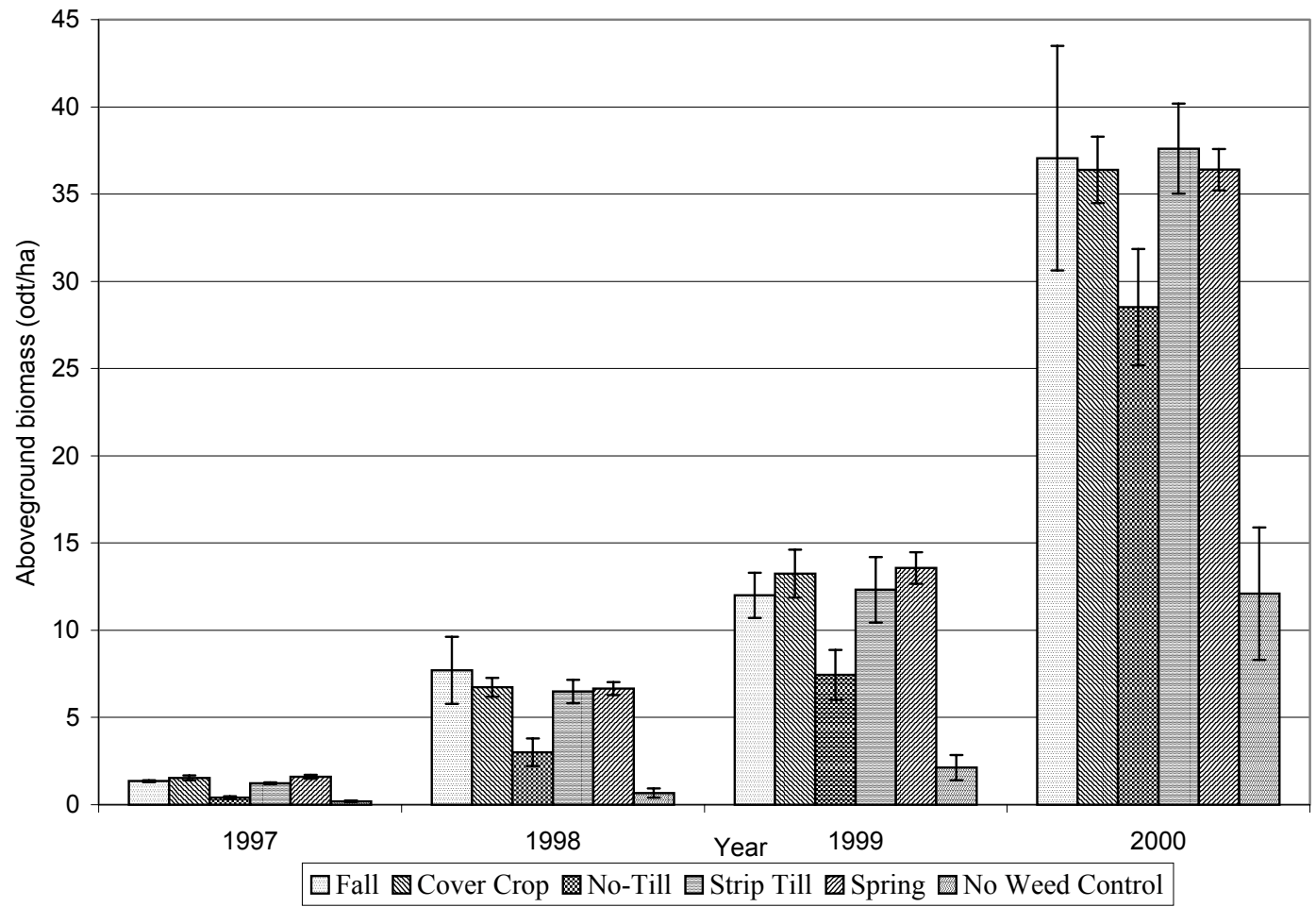


Figure 6. Aboveground biomass (mean \pm standard error) of poplar (NM6) biomass crops in six different site preparation treatments over four years in Lafayette, NY.

Table 6. Linear contrasts and p-values for aboveground biomass production over four years for poplar (NM6) and willow (SV1) biomass crops for six different site preparation treatments in Lafayette, NY.

Linear contrast	<u>1997</u>		<u>1998</u>		<u>1999</u>		<u>2000</u>	
	Estimate (odt/ha)	p-value	Estimate (odt/ha)	p-value	Estimate (odt/ha)	p-value	Estimate (odt/ha)	p-value
Hybrid Poplar (NM6)								
Weed control – No weed control	1.02	<0.0001	5.45	<0.0001	9.58	<0.0001	23.09	<0.0001
Tillage – No tillage	1.02	<0.0001	3.89	<0.0001	5.34	<0.0001	8.35	0.0240
(Fall + Cover Crop) – Spring	-0.16	0.0392	0.56	0.5002	-0.95	0.4792	0.32	0.9340
Fall – Cover crop	-0.21	0.0205	0.98	0.3114	-1.24	0.4242	0.67	0.8824
Spring – Strip tillage	0.36	0.0002	0.17	0.8627	1.24	0.4233	-1.21	0.7890
Willow (SV1)								
Weed control – No weed control	0.02	0.8224	0.51	.04915	2.68	0.0304	13.19	0.0005
Tillage – No tillage	0.02	0.7798	0.52	0.4904	3.34	0.0091	16.90	<0.0001
(Fall + Cover Crop) – Spring	0.0	0.9786	0.04	0.9590	-0.99	0.4627	- 6.14	0.1225
Fall – Cover crop	-0.02	0.8474	-0.65	0.4970	-1.47	0.3451	-7.61	0.0981
Spring – Strip tillage	0.02	0.8392	0.63	0.5119	3.64	0.0230	14.55	0.0025

rotation the weed control treatments produced 23.1 odt ha⁻¹ more biomass than the no weed control treatments and the tilled treatments produced 8.4 odt ha⁻¹ more biomass than the no-till treatment.

The no-till and no weed control treatments were consistently ranked fifth and sixth out of six in terms of aboveground biomass production. The ranking of the remaining four treatments changed over the rotation. In 1997 the strip tillage treatment was ranked fourth and had significantly less aboveground biomass than the spring tillage treatment ($p = 0.0002$). However, by the end of the first rotation the strip tillage treatment had produced the most aboveground biomass, although it was not significantly different from the fall tillage, spring tillage, or cover crop treatments.

Willow – SV1

Establishment year aboveground biomass production for the willow (SV1) ranged from 0.01 to 0.04 odt ha⁻¹ and was not different among the site preparation treatments (Figure 7, Table 6). Estimated aboveground biomass in the first (1998) and second year (1999) of coppice growth after cutback ranged from 0.02 to 1.0 odt ha⁻¹ and 0.1 to 4.9 odt ha⁻¹ respectively. Treatment effects on aboveground biomass production were evident beginning the first year after cutback. In 1998 the average production of treatments with weed control was 0.5 odt ha⁻¹ greater than treatments without weed control. This difference expanded in 1999 to 2.7 odt ha⁻¹. In the second-year after cutback (1999) the tilled treatments had 3.3 odt ha⁻¹ more aboveground biomass than the no-till treatment ($p = 0.0091$) and the spring tillage treatment had 3.6 odt ha⁻¹ more aboveground biomass than the strip tillage treatment.

At the end of the first three-year rotation aboveground biomass ranged from 0.4 odt ha⁻¹ in the no-till and no weed control treatment to 24.0 odt ha⁻¹ in the spring tillage treatment. The difference in aboveground biomass production between the weed control and no weed control treatments was 13.2 odt ha⁻¹. The tilled treatments produced 16.9 odt ha⁻¹ more aboveground biomass than the no-till treatment. The spring tillage treatment produced 14.6 odt ha⁻¹ more aboveground biomass than the strip tillage treatment.

Aboveground biomass production was 7.6 odt ha⁻¹ higher in the cover crop treatment compared to the fall tillage treatment.

The ranking of the treatments in terms of aboveground biomass changed little from the establishment year to the end of the first rotation. The cover crop and spring tillage treatments were consistently ranked first or second out of six treatments. The fall tillage treatment and strip tillage treatments were consistently ranked third and fourth respectively. The no-till and no weed control treatments consistently had the lowest biomass production and were ranked fifth or sixth.

Discussion

Survival

Hybrid Poplar – NM6

Survival after the establishment year was greater than 91% for all but the no weed control treatment, which had 84% survival. Survival of 80% has been suggested as a cutoff between successful and failed establishment for high density SRWC (Bergkvist et al. 1996). On this site, if the poplar survived the first year it generally survived through the first rotation indicating that interstool competition did not become a factor in the first rotation. A similar pattern was found in the first rotation for willow (Verwijst 1996), but interstool competition increased in the second and third rotations resulting in increased mortality. NM6 planted at a similar (Tharakan et al. 2001) or lower density (Hansen et al. 1984b, Hansen et al. 1986, White et al. 1991) had high survival rates and a minimal amount of mortality over the first three to four years. Poplar planted at a higher density of 40,000 plants ha⁻¹ (DeBell et al. 1986) or 111,000 plants ha⁻¹ (Kopp et al. 2001) resulted in significant drops in survival over a seven and ten year period respectively.

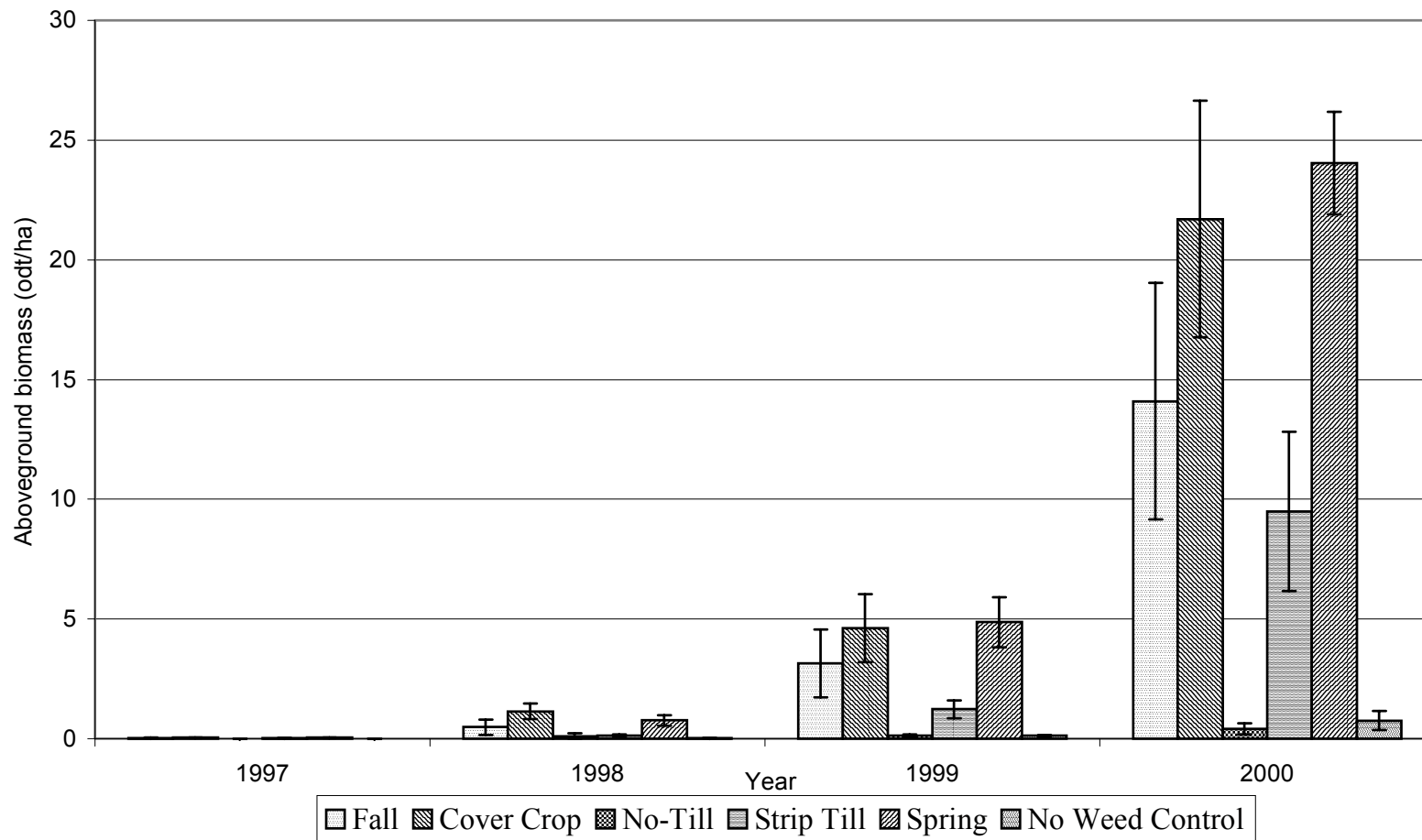


Figure 7. Aboveground biomass (mean \pm standard error) of willow (SV1) biomass crops in six different site preparation treatments over four years in Lafayette, NY.

In this study the only site preparation treatment that had a significant affect on survival during the first rotation was the no weed control treatment. The effect of different site preparation techniques on the survival of poplar varies among studies. White et al. (1991) reported no difference in survival between tilled and no-till plots planted with hybrid poplar planted at 10,000 trees ha⁻¹. Survival ranged from 85 to 92% and was not different among five site preparation treatments in an irrigated trial with hybrid poplar planted at 1,200 trees ha⁻¹ (Hansen et al. 1984b). Clay and Dixon (1996) found that varying degrees of weed competition had no effect on the establishment year survival of high-density (~15,000 plants ha⁻¹) hybrid poplar. However, in the first year of growth after cutback, mortality of the poplar stools was greater than 80% on the plots with heavy weed competition. In contrast, Hansen et al. (1986) reported that mortality of two hybrid poplar clones was 5% on tilled treatments compared to 15% on no-till treatments.

Willow – SV1

The pattern of survival for willow on this site over the first rotation was different from the hybrid poplar. Survival after the establishment year was greater than 84% for all treatments. High initial survival appears to be a characteristic of SV1. In 10 out of 11 clone-site trials in the northeastern United States SV1 establishment year survival was greater than 90% (Tharakan et al. 2001). Following cutback in this study, survival declined in the no-till, strip tillage, and no weed control treatment so that by the end of 1999 survival was below 80% on all three treatments. The spring tillage, fall tillage, and cover crop treatments all maintained survival of greater than 84% over the first rotation. Verwijst (1996) found that mortality was only 4.3% in a stand of *Salix viminalis* three years after establishment at a density of 20,400 plants ha⁻¹. Following the first harvest stand mortality increased progressively through the second and third rotations so that cumulative mortality was 43.8 and 65.0% respectively. This mortality was attributed to competition among the willows. To have a positive biomass increment a stool had to maintain a minimum weight, which was determined to be 44, 526 and 887 g/stool one, two and three years after harvest respectively (Verwijst 1996). Although this value would vary by clone, site, planting density, and management practices it provides a guideline for

assessing the vigor of the stools in this study. The first year after cutback (1998) the average stool weight ranged from 1.7 g in the no weed control plots to 89.0 g in the cover crop plot. Only the cover crop and spring tillage treatments were greater than 44g. By the end of 1999 the individual stool weight for the no-till and no weed control treatments were 18 g and 13 g respectively, while the other treatments ranged from 115 g to 374 g. In contrast individual poplar stool weights in this study ranged from 191 g to 998 g in 1999. Smaller willow stools in this study probably did not die due to competition with other willows. However, their small size may have made them susceptible to competition with the surrounding weeds, especially in 1999, which was an extremely dry year.

Biomass Production

Hybrid Poplar – NM6

Establishment year biomass production for NM6 ranged from 0.2 odt ha⁻¹ to 1.5 odt ha⁻¹. The four best treatments (spring tillage, cover crop, fall tillage and strip tillage) all had production greater than 1.2 odt ha⁻¹, which is in the middle of the range of values reported from trials where NM6 was grown at a comparable density and with management practices similar to the fall or spring tillage treatments (Table 7).

In the first year of coppice growth after cutback estimated biomass production ranged from 0.7 to 7.7 odt ha⁻¹. The four best treatments had values greater than 6.5 odt ha⁻¹ and were not significantly different from each other. This study was not fertilized until the second year after cutback. Estimated aboveground biomass of NM6 in unfertilized plots at the three other sites in New York was similar to the values in this study, ranging from 1.21 to 8.0 odt ha⁻¹ (Ballard et al. 2000). After the second year of coppice growth aboveground biomass in this study was estimated at 2.1 to 13.6 odt ha⁻¹, with the four best treatments being above 12.0 odt ha⁻¹. These estimated values were below the lowest levels reported on three other sites in New York. Production in the second year after cutback in this trial was probably limited by the severe drought in 1999. The data for second year after cutback data in Table 7 was collected after the 1997 growing season. The Tully trial reported in Adegbidi et al. (submitted) was in the first year of growth

following harvest (i.e. on a five-year-old root system) in 1999 and only produced half of what it had in the first year of growth after cutback on a two-year-old root system (unpublished data).

Growth in the third year after cutback in this trial was exceptional, so that final biomass production ranged from 36.4 to 37.6 odt ha⁻¹ for the four best treatments. This was greater than the NM6 yields recorded at the three other sites in New York and one in Vermont, which ranged from 23.4 to 32.8 odt ha⁻¹ (unpublished data). The no-till treatment yield (28.5 odt ha⁻¹) was at the low end of the range of values from the other studies.

The first three-year rotation yields were not significantly different among the four best treatments, all of which reached the projected first rotation yield of 12 odt ha⁻¹ yr⁻¹ (Abrahamson et al. 1998). Treatment effects that were apparent among the four best treatments in the establishment year were not evident after cutback (Table 6). In the first and second year of coppice growth after cutback estimated aboveground biomass in the no-till treatment was 39% and 55% less respectively than the best treatment. By the end of the first rotation the yield on the no-till treatment was 28.5 odt ha⁻¹, or about 24% less than the best treatment. This reduction was similar to what Hansen (1986) reported on an excessively drained sand, but much less than what occurred on a poorly drained loam. In contrast, McKittrick (1990) found that the standing volume of clone DN55 was similar on no-till and cultivated treatments. Clay and Dixon (1996) found that poplar and willow biomass crops that had lower production during establishment and immediately following cutback due to weed competition had an ability to make up some of this difference over time. Not controlling weeds in this trial decreased first rotation poplar yields by 23.0 odt ha⁻¹ compared to cultivated treatments, supporting the assertion that weeds must be controlled if SRWC are to be productive (Danfors et al. 1998, Labrecque et al. 1994, Volk et al. 1999).

Table 7. Aboveground biomass production of poplar (NM6) and willow (SV1) biomass crops in other trials grown at similar densities in the Northeastern United States. All trials were established using a combination of mechanical and chemical weed control similar to the fall or spring tillage treatments in this trial, were fertilized with 100 Kg N ha⁻¹ in the first year after cutback, and were not irrigated.

Location	Establishment year (odt/ha)	First year after cutback (odt/ha)	Second year after cutback (odt/ha)	Harvest (odt/ha)	Source
Hybrid Poplar – Clone NM6					
King Ferry, NY		4.0	13.0	23.4 ¹	Ballard et al. 2000
Sommerset, NY		7.0	17.9	27.8 ¹	Ballard et al. 2000
Tully, NY		10.4	21.1	32.8 ¹	Ballard et al. 2000
Tully, NY	1.5	6.2		33.8 ¹	Tharakan 1999
Burlington, VT				31.4 ¹	
Delaware	3.1				Volk et al. 2000a
Roaring Branch, PA	0.1				Volk et al. 2000b
Willow – Clone SV1					
Tully, NY		10.9	19.6	31.5	Adegbidi et al. (submitted)
King Ferry, NY		2.4	8.9	16.2 ¹	Ballard et al. 2000
Sommerset, NY		4.4	17.5	27.1 ¹	Ballard et al. 2000
Tully, NY		10.0	21.3	28.2 ¹	Ballard et al. 2000
Tully, NY	0.8	7.2		22.3 ¹	Tharakan 1999
Burlington, VT				25.4 ¹	
Lafayette, NY					
Tully, NY – First Rotation				26.8	Volk et al. (in press)
Tully, NY – Second Rotation				32.1	Volk et al. (in press)
Delaware	0.1				Volk et al. 2000a
Roaring Branch, PA	0.02				Volk et al. 2000b

Note ¹ indicates that this is currently unpublished data

Willow – SV1

Establishment year production of willow clone SV1 in this trial ranged from 0.01 to 0.04 odt ha⁻¹, which is at the low end of values from other studies where SV1 was grown at similar densities and with management practices comparable to the fall or spring tillage treatments (Table 7). Establishment year biomass production of SV1 is typically an order of magnitude less than hybrid poplar clones, which may be due to differences in the rate and peak of leaf area development. Ten and eighteen weeks after planting NM6 leaf area was 0.18 m² and 0.92 m² compared to 0.08 m² and 0.19 m² for SV1 (Tharakan 1999).

First year coppice production after cutback of SV1 in this study was 0.02 to 1.1 odt ha⁻¹. This trial was not fertilized until the beginning of the second year of coppice growth. Estimated aboveground biomass in unfertilized plots at three other sites in New York ranged from 0.5 to 5.8 odt ha⁻¹ (Ballard et al. 2000). Relative growth rates in the first year of coppice growth after cutback in this trial were 100 to 2,750%, but establishment year production was low in this study. Relative growth rates in the second (9 – 778%) and third year (250 – 672%) after cutback continued to be high, except in the no-till treatment in spite of the severe drought conditions in 1999. Estimated annual growth increments in the third year of coppice growth were 19.4, 17.1 and 11.0 odt ha⁻¹ respectively for the spring tillage, cover crop and fall tillage treatments. Estimated mean annual increments as high as 36.5 odt ha⁻¹ have been recorded for irrigated plots of SV1 (Kopp et al. 1997). Once SV1 was established and occupying the site, its production potential was expressed. However, in the best treatments in this study it took two to three years for the willow to dominate the site, which reduced first rotation yields.

Aboveground biomass production ranged from 0.4 to 24.0 odt ha⁻¹ at the end of the first rotation. Production of the best treatments – spring tillage (24.0 odt ha⁻¹) and cover crop (21.7 odt ha⁻¹) - was at the low end of first rotation values for unirrigated trials in the region. The low production in the establishment year and first two years of coppice

growth restricted the first rotation aboveground production. Weed competition was probably the largest single factor limiting production (Danfors et al. 1998, Labrecque et al. 1994, Volk et al. 1999) and it was compounded by the lack of moisture in 1999. Not controlling weeds in this study significantly decreased first rotation willow yields by 13.0 odt ha⁻¹ compared to the treatments with weed control. Reduced tillage site preparation techniques were not effective for establishing SV1 on this site. The no-till treatment reduced first rotation production on this site by 97%, similar to reductions reported for no-till poplar (Hansen 1986) and willow (Clay and Dixon 1996). Strip tillage reduced willow production by 60%, similar to the results for hybrid poplar reported by Von Althen (1981).

Summary

First three-year rotation results from this study indicate that the spring tillage, cover crop, or strip tillage treatments are viable alternatives to the standard complete fall tillage treatment for NM6 on this site. All these treatments produced over 36 odt ha⁻¹ in the first rotation. The three alternatives to the standard fall tillage treatment will be helpful in reducing erosion potential on many sites by providing some ground cover during the establishment phase. One of the challenges of using alternative site preparation treatments is that they often produce different results depending on the field history and soil characteristics (Hansen 1986). The site in this study appears to be good for NM6 production. Caution should be taken when transferring these results to other sites that have different soil and site history characteristics

For willow clone SV1 the spring tillage and cover crop treatments produced the best results followed by the fall tillage treatment. However, first-rotation yields at this site were low relative to other trials in the region. It is unclear why the fall tillage treatment, which is currently the standard practice, produced less biomass over the first three-year rotation compared to the spring tillage and cover crop treatments. The poor establishment

year growth of the willow on this site, which may have been due to a combination of weed competition and soil characteristics, clearly effected its production over the first three-year rotation. Additional ongoing analysis of soil and foliar nutrient characteristics and levels of weed competition may help explain some of the differences between the treatments and the low overall production. These analyses will be included in the final report for this study.

The cover crop treatment was as or more effective than the fall tillage treatment for both NM6 and SV1. Cover crops can improve soil characteristics such as infiltration, organic matter and soil nutrient levels while reducing erosion potential. Further studies are underway to examine how to effectively incorporate cover crops during the establishment of willow and poplar biomass crops.

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