The Effect of Weed Control Method on Soil Nutrient Availability and Growth of Different Hybrid Poplar Clones

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Abstract

During the early establishment phase outplanted hybrid poplar seedlings are the most vulnerable to lethargic growth or mortality because of interspecific competition with non-crop plant species for available soil moisture and nutrients. Consequently, there is a need to develop practical weed control practices that are not only successful at controlling non-crop plant species, but also cost-effective for producers looking to minimize their input costs. The objectives of this two-year study were to: i) evaluate the effects of different combinations of in-row (plastic mulch, herbicide, and control) and between-row (tillage, herbicide, and control) weed control practices on soil nutrients bioavailability and the early growth of four hybrid poplar clones (Walker, Assiniboine, WP-69, and Hill) and, ii) assess the relationship between growing season soil nutrient supply rates, measured using *in situ* burials of ion-exchange membrane (Plant Root Simulator™-probes), and growth of different hybrid poplar clones. Determining the effects of different weed control practices on growth-limiting edaphic properties and subsequent seedling growth should help to support effective management strategies, in terms of selecting an efficacious and cost-effective weed control strategy that promotes the establishment and growth of hybrid poplar seedlings, while minimizing the input costs incurred by the producer.

Introduction

Agroforestry, in one form or another, has been practiced in Saskatchewan for more than a hundred years and has utilized tree species in many capacities, including shelterbelts, riparian buffers, fuel, furniture and building materials, and for soil stabilization. Although the end uses of trees remain relatively unchanged today, there are three additional immerging incentives for farmers to grow trees, namely: i) their ability to sequester large quantities of carbon in their above- and below-ground tissues, which will be advantageous given the obvious carbon offset potential of large-scale plantations, in terms of their national importance as Canada strives to meet its Kyoto Protocol commitment; ii) perennial woody biomass can be a sustainable source of bioenergy (i.e. energy derived from biomass), therefore, providing a valuable renewable/cleaner alternative to finite petroleum-based fuels. Specifically, the conversion of woody biomass into fuel (i.e., solid, liquid or gaseous), heat, and electricity for industrial, commercial, or domestic use is increasingly attractive. Furthermore, the unsustainable reality of grain-based ethanol production is quickly becoming apparent, when compared with the use of woody biomass, and finally iii) the use of the woody constituents in the production of emerging engineered products, such as bioplastics.

Before there is widespread adoption of agroforestry practices in Saskatchewan, however, a clear economic advantage for producers to grow hybrid poplar must become apparent. In order to achieve this goal, there needs to be adequate survival and growth of planted seedlings, especially within the first few years. During the early establishment phase, outplanted hybrid poplar seedlings are most vulnerable to lethargic growth or mortality, because of interspecific competition with non-crop plant species for available soil moisture and nutrients. When growing hybrid poplar on agricultural lands possessing large seed banks, a need exists, therefore, to develop practical weed control methods that are not only successful at controlling non-crop plant species, but also cost-effective for producers looking to minimize their input costs. The objectives of this study, therefore, were to: i) Evaluate the effects of different combinations of in-row (IR) and between-row (BR) weed control methods on soil nutrient bioavailability and the early growth of hybrid poplar clones (Fig. 1) and ii) Assess the relationship between growing season soil nutrient supply rates, measured using *in situ* burials of ion-exchange membrane (Plant Root Simulator (PRS)™-probes; Fig. 2), and the growth of different hybrid poplar clones in northern Saskatchewan.

Figure 1. Examples of different in-row (IR) and between-row (BR) weed control methods used.

Materials and Methods

Study site

The data for this study were collected from a hybrid poplar plantation located in northern Saskatchewan, approximately 25 km southwest of Meadow Lake (SW 31 57 19 W3). The topography of the site is very gently undulating (i.e., slopes less than two percent) and the soil and site characteristics are reported in Table 1.

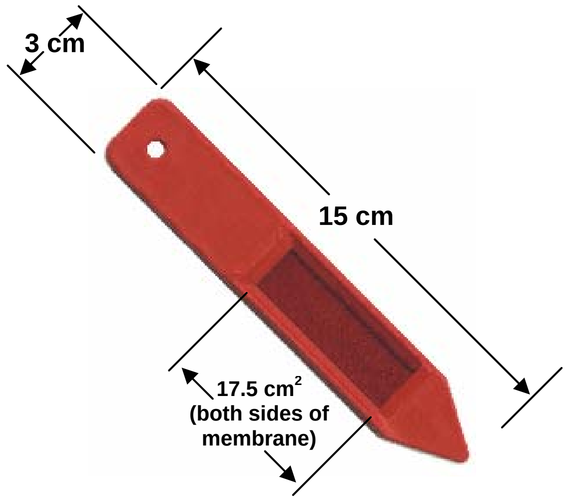

Figure 2. Dimensions of PRS™-probe used to measure soil nutrient availability *in situ*.

Table 1. Selected characteristics of hybrid poplar (HP) study site located near Meadow Lake, SK.

Soil Characteristics					**Site Characteristics**			**Vegetation Management Practices**	
Soil Association	***Soil Type***	***Texture***	***pH***	***EC (mS/cm)***	***Prior Crop (year HP planted)***	***ACC****	***Rainfall† (mm)***	***Pre-planting***	
								Mechanical	***Chemical***
Bittern Lake‡	Brunisolic Gray Luvisol	sandy-loam to loam	5.4	0.7	pasture (2004)	4-5	334 (2004) 412 (2005)	Deep till (x2)	- Glyphosate (2.5 L/ha) - Linuron (4 kg/ha)

* Agriculture Capability Classification (Class 4: severe limitations; Class 5: very severe limitations).
† During the period of PRS™-probe burials.
‡ For a complete description (i.e., map unit, parent material, stoniness, drainage, etc.) see SCSR (1995).

Experimental design

The experimental design was a 3 x 3 x 4 factorial, split-split plot design, replicated three times (Figure 3). The treatments included: three IR treatments (plastic mulch, herbicide, and control), three BR treatments (tillage, herbicide, and control), and four hybrid poplar clones (Walker, Assiniboine, WP-69, and Hill). Within each plot there were 25 trees within each row comprised of five trees of each clone with a IR and BR spacing of 2.5 and 3.5 m, respectively. Each treatment was buffered by a row of Walker hybrid poplar. Additionally, three replicates of alternative weed control treatments were included for comparison purposes: i) carpet (100% continuous filament nylon Shaw™ broadloom carpet with a traffic rating of 3.5, Shaw Industries Inc., Dalton, GA, USA), ii) hardwood chips (80 % trembling aspen and 20 % balsam poplar; C:N

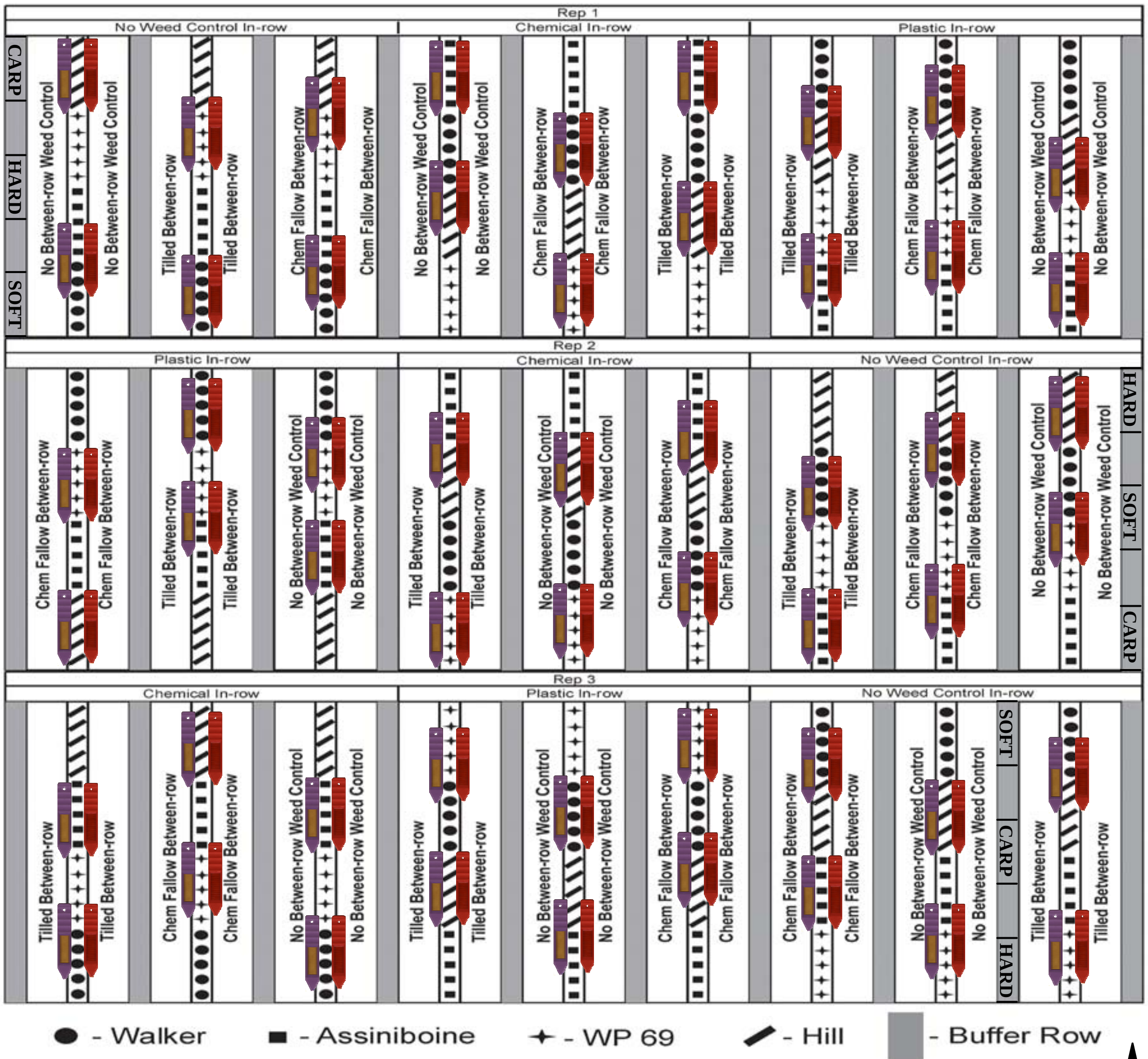

Figure 3. Experimental design used to assess the effects of different weed control practices on the establishment and growth of four hybrid poplar clones (Source: Garth Inouye, AAFC-PFRA). Location of the three alternative weed control treatment (carpet, CARP; hardwood wood chips, HARD; and softwood woodchips, SOFT) plots and PRS™-probes are also indicated.

of 1013), and iii) softwood chips (33 % white spruce, 33 % black spruce, and 33 % jack pine; C:N of 1476) (Figure 4). In order to avoid the confounding effects of other imposed treatments on these alternative treatments, each of the carpet and wood chip plots (85 x 45 cm) were placed within the control plots (i.e., no weed control IR/no weed control BR; Figure 4).

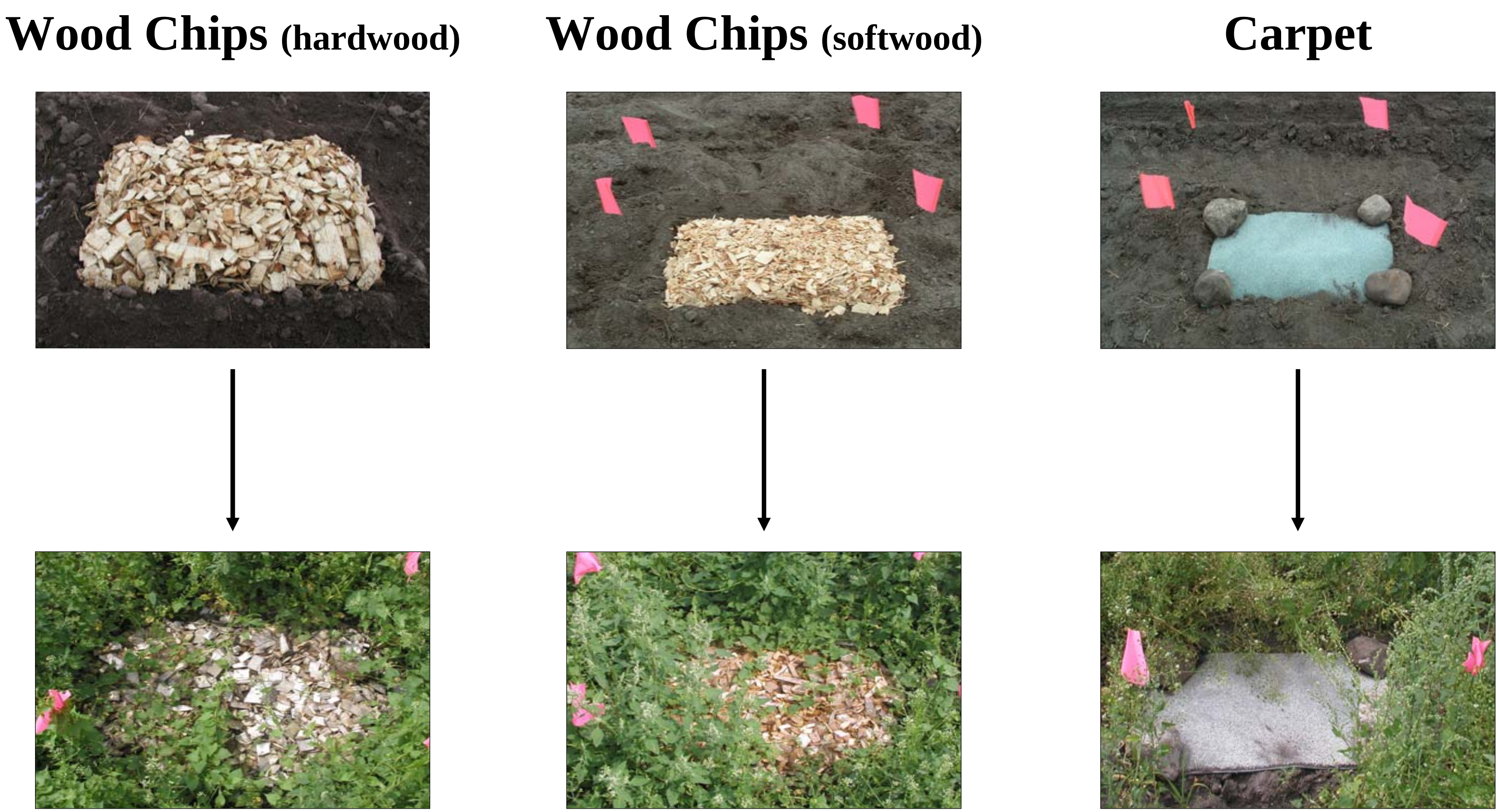

Figure 4. Three alternative weed control practices after installation in early May (top row) and in late July (bottom row) 2004.

Soil nutrient analysis

Plant Root Simulator™-probes (Western Ag Innovations Inc., Saskatoon, SK) were used to measure soil nutrient availability at each site. Plant Root Simulator™-probes provide a basis for determining fertilizer recommendations for different cereal, oil seed, pulse, and forage crops in western Canada (Qian and Schoenau 2002) and have been used to study forest soil nutrient dynamics in both undisturbed and disturbed sites (Huang and Schoenau 1996,1997; Johnson et al. 2001; Duarte 2002; Hangs et al., 2004). The PRS™-probe consists of either cation- or anion-exchange resin membrane encased in a plastic holding device and is inserted into soil to measure nutrient supply rates *in situ* with minimal disturbance. The PRS™-probes were inserted vertically into the Ap horizon, thereby having the ion-exchange membrane effectively measure soil nutrient supply rates in the zone having the largest concentration of hybrid poplar roots (Block, 2004). The PRS™-probes were left in the soil and then replaced with fresh PRS™-probes twice more during the growing season for a total of 12 and 15 weeks in both 2004 and 2005, respectively (only the 2005 data are reported). Continuously measuring soil solution nutrient availability should provide a basis for accurately predicting nutrient supply-limited uptake or growth, because it is an integral part of the mechanisms governing nutrient supply and uptake (Lajtha et al., 1999; Smethurst, 2000). Consequently, replacing fresh PRS™-probes in the same soil slot provides a reliable *in situ* measure of temporal nutrient availability and yields the most accurate index of nutrient availability to correlate with seedling growth.

After removal, the PRS™-probes were washed free of soil and then thoroughly scrubbed and re-washed back in the lab prior to the analysis to ensure complete removal of any residual soil. The PRS™-probes within each treatment plot were combined for analysis, much like a composite soil sample, and this helped to account for any microscale variability. Inorganic N as ammonium (NH_4^+-N) and nitrate (NO_3^--N) was determined colourimetrically and the remaining nutrients (P, K, S, Ca, Mg, Cu, Zn, Mn, Fe, and B) measured using inductively-coupled plasma spectrometry. Unused PRS™-probe method blanks also were analysed to test for contamination during the regeneration and handling steps.

Seedling survival and growth

At the end of each growing season, seedling establishment and growth were assessed within each plot by measuring seedling survival, ground-line diameter (GLD), and height. Determining the relationship between soil nutrient supply rate at both time of planting and throughout each growing season and subsequent seedling growth within each of these different weed control plots should help determine effective management strategies, in terms of selecting effective weed control practices that support successful hybrid poplar plantation productivity.

Statistical analyses

The soil nutrient availability and seedling growth data were analysed using the GLM procedure in SAS (Version 8.0, SAS Institute Inc. Cary, NC). Mean comparisons were performed using least significant differences (LSD) at a significance level of 0.05. The LSD option was used to carry out pair-wise *t* tests (equivalent to Fisher's protected LSD) of the different means between treatments. All data were tested for homogeneity of variances and normality. Simple linear regressions were performed using the REG procedure in SAS (Version

8.0, SAS Institute Inc. Cary, NC) using pooled data (i.e., all treatments) to quantify the relationship between the nutrient supply rate data during the growing season and growth of hybrid poplar seedlings over that same period. Residuals from the analyses were examined to the test the assumptions of equal variance and no data transformations were necessary.

Results and Discussion

Soil nutrient bioavailability in different weed control method plots

The implication of this study is obvious; it is important to quantify the effects of these various weed control practices on soil nutrient supply rate and ultimately seedling growth, in order to determine which treatment(s) benefit seedling growth the most with the least input cost. When placed among plant roots, the PRS™-probes will provide a *net nutrient supply rate* (i.e., measuring the difference between total soil nutrient supply and plant uptake); therefore, yielding a measure of *nutrient surpluses* rather than *net mineralization* over the burial period. Unlike other PRS™-probe studies, here it is advantageous not to use root exclusion cylinders (i.e., PVC pipe) with these long-term PRS™-probe burials, because the objective is to quantify the ability of each of the weed control treatments to reduce the below-ground interspecific competition for nutrients and this is easily done by comparing the net nutrient supply rates among the treatments. In other words, a treatment with larger nutrient supply rates than the control indicates that there was reduced below-ground competition for soil nutrients and, therefore, the treatment was more effective at minimizing the negative effects of competing non-crop species for soil resources.

The different combinations of IR/BR weed control methods increased the bioavailability of soil nutrients during both the 2004 (N, K, S, and Zn; data not shown) and 2005 (N, S, Cu, and Zn; Table 2) growing seasons compared with the control plots. Specifically, treatments 3, 7, 9, and 11 (herbicide IR/no weed control BR, no weed control IR/herbicide BR, no weed control IR/tilled BR, and hardwood chips, respectively) were the only treatments to not increase NO_3^--N and total N supply rates. In addition, treatments 1, 4, and 6 (herbicide IR/tilled BR, plastic mulch IR/tilled BR, and plastic mulch IR/herbicide BR, respectively) increased S supply rates compared with control plots.

Looking at the temporal variations in total N supply rates over the growing season, unlike the first year of this study where there were no differences among the treatments in the first few weeks of the season (due to the relative lack of non-crop vegetation following site preparation the previous fall; data not shown), in the second year, the effects of increasing below-ground biomass of competing root systems on soil N availability was evident early on in spring (Figure 5). As the season progressed, the growth of weeds intensified and the increased level of competition for soil N among the different vegetation management was readily apparent and depending on the treatment and time of season, the nutrient supply rates decreased from 12 to 98% compared with the 2004 measurements. Presumably, as the root length densities of non-crop species continue to increase every year, this trend will continue. Similar with 2004, the plastic mulch treatments worked very well until towards the end of the season when the total N supply rates within these treatments dropped dramatically (Figure 5), suggesting that weed roots finally grew underneath the plastic mulch and were competing for N with the seedlings.

The most surprising aspect of the 2004 data was the lack of significant differences among nutrient availability in terms of the effects of the different combinations of weed control practices on growing season nutrient availability relative to the control plot. This was the result

Table 2. Mean (n=3) cumulative soil nutrient supply rates, measured using *in situ* burials of PRS™-probes, from early May to late August, 2005 in plots with different weed control techniques applied in-row (IR) and between-row (BR) compared with a control (highlighted).

Treatment*	NH_4^+	NO_3^-	Total N	P	K	S	Ca	Mg	Cu	Zn	Mn	Fe	B
	μg/10cm²/15 weeks												
1	16abc†	1054a	1070a	94.1a	576ab	178abc	5712a	1140b	1.1a	6.1ab	27.1ab	88.1abcd	3.5bc
2	16abc	582bcd	598bcd	109.1a	366ab	138bcde	6043a	1180b	0.7cdef	6.1abc	23.8ab	54.0def	3.9abc
3	19ab	266defg	285def	175.9a	335ab	174abcd	5165a	1109b	0.5efg	3.3bcd	32.9ab	41.4ef	3.3bc
4	21a	1052a	1073a	39.3a	585ab	230a	5479a	964b	1.0ab	4.7abcd	52.1a	124.4a	4.4ab
5	11abc	885ab	896ab	36.2a	440ab	132cde	4755a	990b	0.9abc	4.6abcd	16.9b	108.4ab	3.7abc
6	15abc	763abc	778abc	75.4a	514ab	189abc	5473a	1032b	0.8bcd	6.3a	30.1ab	97.3abc	3.0c
7	14abc	120fg	133f	32.5a	107b	100de	5034a	1095b	0.3g	2.7d	8.3b	34.8ef	3.5bc
8	15abc	69g	84f	83.8a	369ab	98d	4640a	1080b	0.3g	2.2d	9.4b	28.1f	3.5bc
9	22a	144efg	166ef	61.6a	450ab	215ab	5331a	1047b	0.4fg	3.2cd	9.8b	35.9ef	3.6abc
10	8c	474cde	482cde	17.7a	411ab	129cde	5136a	1235ab	0.7cdef	3.2cd	16.5b	78.3bcde	4.7a
11	9bc	239efg	248ef	64.1a	467ab	92e	4890a	1220ab	0.6defg	3.3bcd	10.7b	51.4def	4.0abc
12	8c	409def	417def	169.1a	759a	114cde	5503a	1639a	0.7cd	4.6abcd	10.0b	57.1cdef	4.1ab

* 1=herbicide IR/tilled BR; 2=herbicide IR/herbicide BR; 3=herbicide IR/no weed control BR; 4=plastic mulch IR/tilled BR; 5=plastic mulch IR/no weed control BR; 6=plastic mulch IR/herbicide BR; 7=no weed control IR/herbicide BR; 8=no weed control IR/no weed control BR; 9=no weed control IR/tilled BR; 10=carpet; 11=hardwood wood chips (C:N=628); 12=softwood wood chips (C:N=284).

† For each site, means within a column followed by the same letter are not significantly different (P >0.05) using LSD.

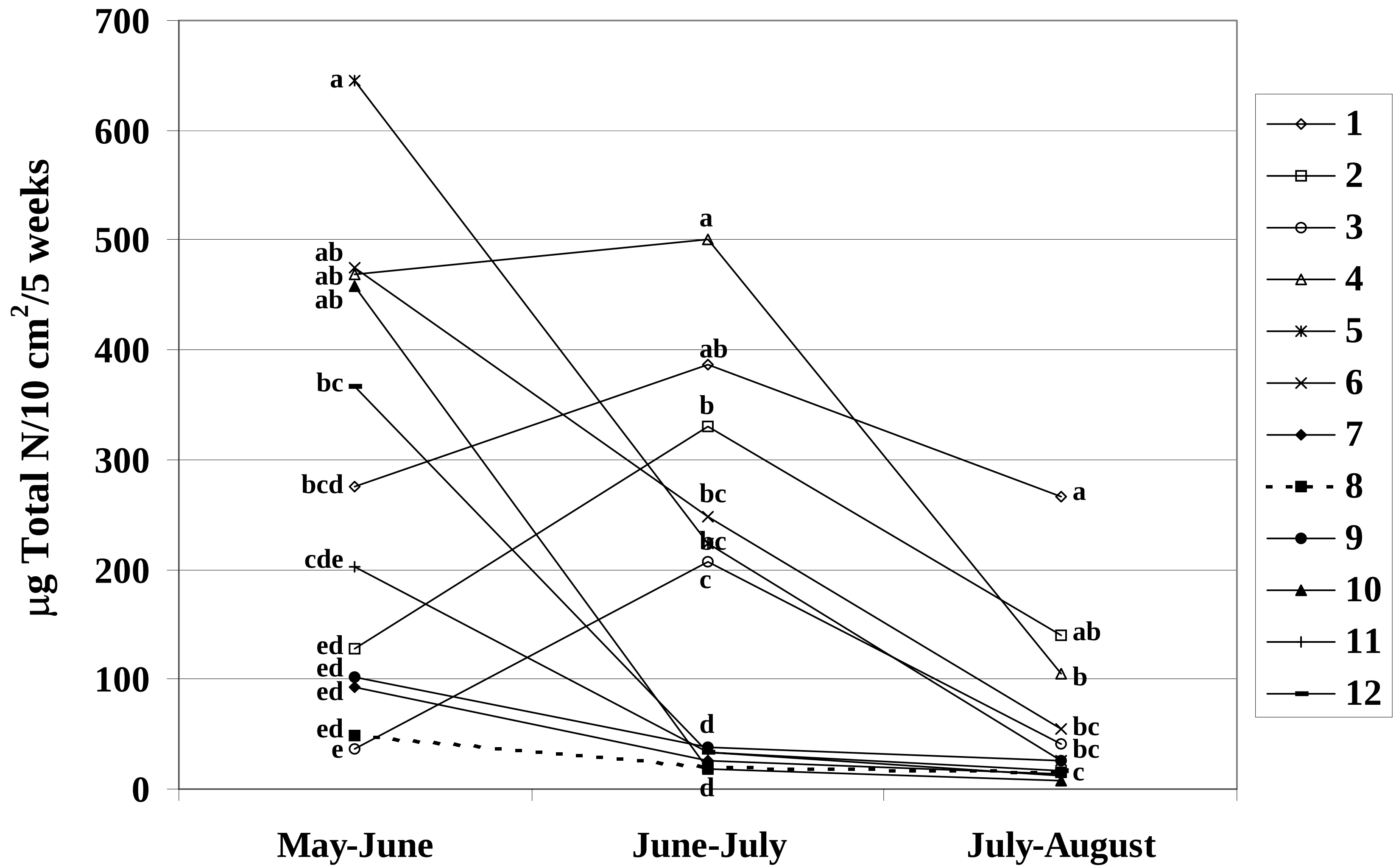

Figure 5. Mean (n=3) total N supply rates, measured using in situ burials of PRS™-probes, during 2005 in plots with different weed control treatments applied in-row (IR) and between-row (BR) compared with a control (dashed line). For each burial period, means having the same letter are not significantly different (*P* >0.05) using LSD. Treatments: 1=herbicide IR/tilled BR; 2=herbicide IR/herbicide BR; 3=herbicide IR/no weed control BR; 4=plastic mulch IR/tilled BR; 5=plastic mulch IR/no weed control BR; 6=plastic mulch IR/herbicide BR; 7=no weed control IR/herbicide BR; 8=no weed control IR/no weed control BR; 9=no weed control IR/tilled BR; 10=carpet; 11=hardwood wood chips (C:N=628); 12=softwood wood chips (C:N=284).

of accidentally applying herbicide IR in the control plots during the first growing season and, therefore, heavily influenced the first year data as indicated by most weed control methods having no significant (P >0.05) difference in soil nutrient supply rates compared with the control in 2004 (data not shown). Clearly, there was no residual effect of this added IR herbicide within the control plots in 2005 given the low N availability measured throughout the entire growing season (Figure 5).

The ability of non-crop vegetation to reduce soil nutrient supply rates results from two principal mechanisms: directly through their competitive uptake of nutrient ions from soil and indirectly through their competitive uptake of soil water, which can greatly diminish the soil moisture content, thereby decreasing the nutrient availability further by increasing the tortuosity pathway of nutrient ions, especially for diffusion-limited nutrients, such as NH_4^+-N, P, K, Cu, and Zn. Certainly, the above-average rainfall at the study site in both 2004 and 2005 would have buffered the below-ground competition for moisture, and its indirect effects on soil nutrient movement, to a certain extent. Presumably, the effects of all these weed control treatments most likely would be more pronounced in a dry year.

Of the three alternative vegetation management practices, the use of carpet seems to be most promising in the short-term given its comparability with the other treatments and its relative abundance as the home renovation trend moves toward hardwood flooring and landfills are inundated with old carpet. At the end of each growing season, a subsample of the hardwood and softwood wood chips were collected from each plot and re-analysed for total C and N and it was found that despite a 45% larger C:N at the beginning of the study, the C:N of the softwood wood chips decreased significantly more (89% decrease to a C:N of 166 after two years) than the hardwood wood chips (73% decrease to a C:N of 272 after two years), with no change in soil pH under either wood chip cover relative to the control. Evidently, the microbial breakdown of the applied wood chips occurred at the expense of inherent soil mineral N supplies, and has been shown to result in chlorotic trees (Dave Halland, personal communication); however, the long-term effect of these wood chip treatments is unknown. This short-term N sink may in fact represent a long-term N source (i.e., slow-release), as this immobilized N is re-mineralized later and made available to the tree when it has a greater capacity to utilize it. The common convention is to try and keep these plantations ‘clean and black’, but these young outplanted seedlings have a limited N uptake capacity within the first few years, so maintaining a weed-free site may not be ideal for long-term site sustainability. Conversely, keeping a vegetation cover on a site is advantageous in terms of minimizing N lost from the ecosystem via N loss pathways (i.e., erosion, leaching, and denitrification), especially on N-deficient sites; however, these non-crop plants are detrimental to seedling survival and growth during the early establishment phase. Therefore, there is an obvious need for a greater understanding of N conservation practices in young hybrid poplar plantations, while providing the N necessary to support accelerated growth. Perhaps a combination of wood chips and fertilization at time of planting, using a point source of controlled-release fertilizer N placed in the planting hole, would provide the necessary vegetation management and nutrient availability at a considerably reduced cost compared with repeated herbicide applications, tillage operations, or the use of expensive plastic mulches.

Hybrid poplar seedling establishment and growth in different weed control method plots

Each year, the combination of plastic mulch IR and either herbicide or tillage BR, supported the largest growth of hybrid poplar (Table 3). Additionally, after factoring in tree growth after two growing seasons, it was clear that any IR weed control practice, regardless of treatment, yielded larger trees compared with the control plots. Based on their growth relative to

Table 3. Mean (n=3) height (HT; cm), ground-line diameter (GLD; cm), and stem volume (VOL; cm^3) growth increments for hybrid poplar seedlings in plots with different weed control techniques applied in-row (IR) and between-row (BR) compared with a control (highlighted).

Treatment*	2004			2005			Since Start		
	HT	GLD	VOL	HT	GLD	VOL	HT	GLD	VOL
CHEM (IR) - Till (BR)	23.3bc†	1.4cd	5.1c	51.0bc	10.9b	205.0b	83.9bc	12.8bc	213.9b
CHEM (IR) - CHEM (BR)	23.6bc	2.0bc	4.7c	71.7b	14.1b	200.0b	104.7b	16.3b	207.2b
CHEM (IR) - CTRL (BR)	26.5bc	1.7cd	6.1bc	60.0b	8.9c	98.4bc	97.2bc	11.3bc	113.4bc
PLAS (IR) - TILL (BR)	50.1a	2.8ab	15.1a	127.6a	23.2a	614.6a	178.0a	26.0a	630.1a
CTRL (IR) – CTRL (BR)	31.1b	2.0bc	8.8bc	34.8c	4.6d	30.9d	65.6d	6.3c	37.9d
PLAS (IR) - CTRL (BR)	56.2a	3.4a	14.0a	71.1b	13.3b	214.0b	125.0ab	16.7b	227.7b
PLAS (IR) – CHEM (BR)	51.7a	3.0a	12.0ab	118.9a	29.0a	862.0a	171.0a	32.4a	888.0a
CTRL (IR) – CHEM (BR)	17.6c	1.1d	3.3c	52.5bc	6.6bcd	82.7bcd	68.6cd	7.7c	86.0cd
CTRL (IR) – Till (BR)	18.6c	1.3cd	3.7c	52.4bc	6.2cd	52.4cd	71.0cd	7.2c	55.5cd

* CHEM = Glyphosate applied at a rate of 1.8 kg ai/ha; TILL = Tillage (10-15 cm deep) using a five-shovel, 60 cm-wide cultivator; CTRL = Control; PLAS = 2.7 mil-thick black polyethylene mulch (125 cm wide).

† Means within a column followed by the same letter are not significantly different (*P* >0.05) by LSD. Each mean is comprised of 20 seedlings, planted as one-year-old rooted cuttings, of four different hybrid poplar clones (Assiniboine, Hill, Walker, and WP-69).

control plots, the poplar clonal differences in sensitivity to below-ground competition were as follows: Assiniboine > Walker > Hill > WP-69 (data not shown). However, when determined on the basis of mortality rate the ranking was as follows: WP-69 > Walker > Assiniboine > Hill, with the greatest mortality for all clones occurring in plots with herbicide applied IR, which suggests that these clones are sensitive to spray drift, especially WP-69 (data not shown).

Relationship between soil nutrient bioavailability and hybrid poplar seedling growth

Across all sites, the total N supply rate often was better correlated with seedling height, GLD, and stem volume growth increment than other nutrients (data not shown). Figure 6 illustrates the strong relationship between total N supply rate measured during the 2004 growing season and the stem volume growth increment (i.e., believed to be the most accurate indicator of overall seedling vigour and growth) of one-year-old hybrid poplar clones, planted as rooted cuttings, in plots with different weed control treatments applied IR and BR.

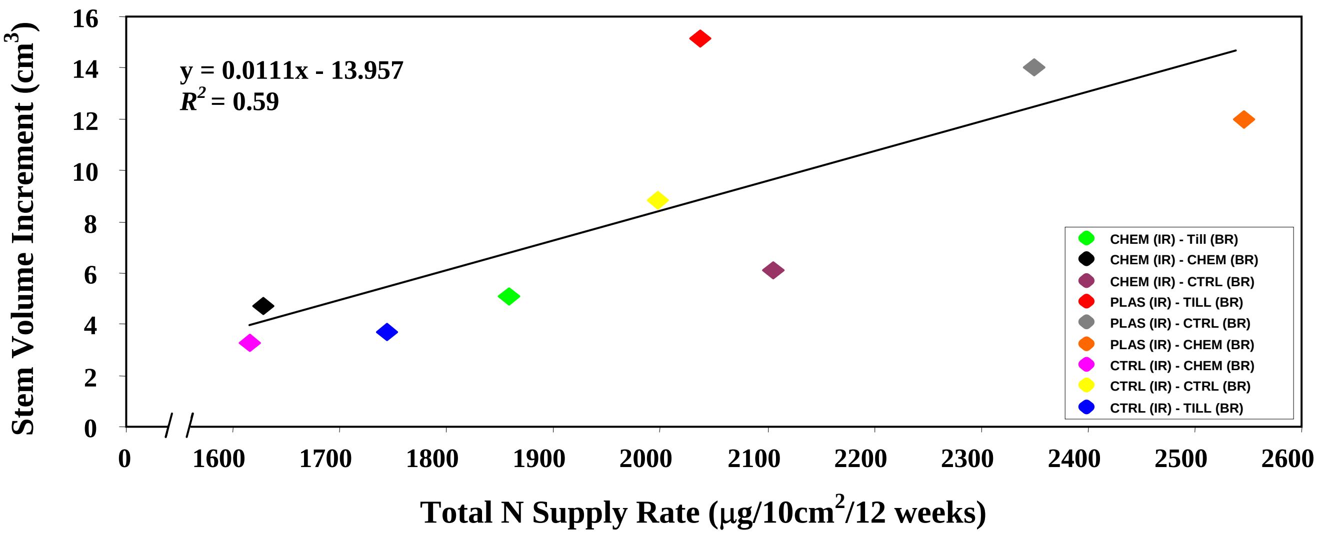

Figure 6. Relationship between total N supply rate, measured using *in situ* burials of PRS™-probes, and seedling stem volume growth increment of four different hybrid poplar clones (Assiniboine, Hill, Walker, and WP-69) in 2004. Each data point is a mean of 20 one-year-old seedlings, planted as rooted cuttings, in plots with different in-row (IR) and between-row (BR) weed control methods. Note: CHEM = Glyphosate applied at a rate of 1.8 kg ai/ha; TILL = Tillage (10-15 cm deep); CTRL = Control; PLAS = 2.7 mil-thick black polyethylene mulch (125 cm wide).

Conclusions

Increased interest in short rotation hybrid poplar plantations within Saskatchewan has prompted a need for the development and demonstration of successful poplar farming management systems. Non-crop vegetation management is the most critical cultural practice in growing hybrid poplars as a plantation crop and, consequently, without adequate weed control, successful poplar farming is not possible. As a result, cost-effective weed control strategies, aimed at minimizing the risks associated with intensive culture of poplars, are essential if widespread grower adoption is to occur. Depending on the treatment, increased below-ground competition for soil resources decreased soil nutrient supply rates from 12 to 98% by the second growing season (data not shown). Presumably, as the root length densities of non-crop species increase annually, this below-ground competition will surely intensify, thereby favouring the selection of efficacious weed control methods. The use of plastic mulch and herbicide, particularly in combination, supported the best early growth of hybrid poplar. However, longer-term (i.e., at least until canopy closure) monitoring is required to determine if these trends continue, in order to assess which treatment(s) yield the most sustained weed control with the least input cost to the producer. Specifically, further research is needed to elucidate whether the short-term growth gains using plastic mulch justify the substantial cost increase (i.e., up to four times) compared with repeated applications of herbicide alone.

The strong correlation existing between the PRS™-probe soil nutrient supply measurements and early growth of the different hybrid poplar clones, demonstrate the utility of the PRS™-probe in assessing soil nutrient dynamics within hybrid poplar plantations. Defining acceptable levels of soil nutrient availability on the basis of measured soil supply rates may have important implications for planning silvicultural practices (i.e., weed control and fertilization requirements) and would advance our understanding of the processes governing the productivity of hybrid poplar plantations. Additionally, determining the effects of different weed control practices on growth-limiting edaphic properties and subsequent seedling growth should help to support effective management strategies, in terms of selecting efficacious and cost-effective weed control strategies that promotes the establishment and growth of hybrid poplar seedlings, while minimizing the input costs incurred by the producer.

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