Poplars and swine manure – Can they be compatible?

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Abstract: The results of two Saskatchewan Agriculture Development Fund (ADF) projects and greenhouse studies are presented. Hybrid poplars are the fastest-growing trees in Saskatchewan and may have economic potential as an alternative crop. They also need more moisture and nutrients annually than other tree species for maximum growth. Under the projects, two hybrid poplar plantings were designed at Arborfield and Preeceville, SK, planted in 2002, which were compatible with field application of swine effluent. The nitrogen response of young hybrid poplar trees in the field was assessed and clonal differences were determined that might make some clones more appropriate in such plantings. Effluent was successfully applied to the two plantings at Arborfield and Preeceville with the Prairie Agricultural Machinery Institute (PAMI) effluent application truck to which modifications to the delivery system had been made. Nitrogen growth response was not shown in the newly-planted trees, but there was an increase in annual growth parameters in older trees at Henribourg, SK even though the final height of the trees did not depend on the nitrogen treatment. The projects showed important clonal differences in growth with Walker, Katepwa, WP69 and a clone of *Populus tristis* (Fisch.) having greater height and diameter than other clones. Greenhouse studies showed that clonal differences exist in nitrogen uptake rates and in preference for the form (ammonium or nitrate) with Hill poplar combining a relatively high productivity with a relatively greater preference for ammonium.

Introduction: The disposal of swine effluent from intensive operations is both a challenge and an opportunity. The effluent slurry contains nitrogen which can be used to fertilize agricultural land but the low concentration of nitrogen makes long-distance transport uneconomical. At the same time, swine producers need to avoid negative environmental impacts such as leaching of nitrogen into groundwater and runoff into water bodies. Swine effluent can be sustainably applied to land to productively use the manure nutrients while minimizing water pollution hazards.

Hybrid poplars are a potential target crop for the safe application of swine effluent because of their fast growth and reportedly high rates of water and nutrient use. Hybrid poplars have been used in many environmental applications around the world and have been found to use large quantities of nitrogen. Examples of the quantities cited are 86 kg/ha/yr for 5-year-old trees in Minnesota (Hansen and Baker 1979), 112 kg/ha/yr for a plantation in Wisconsin (Hansen and Tolsted 1985), 276 kg/ha/yr in Washington (Heilman and Stettler 1986) and as much as 400 kg/ha/yr in a municipal wastewater study at Seattle, Washington (Breuer *et al.* 1977). Stanturf *et al.* (2001) recommended that, for commercial poplar plantations, nitrogen fertilization should begin only after canopy closure and be applied at low rates annually or biennially at rates of between 50 and 100 kg/ha/year. Strand (1986) reported that, even in the first years after planting, hybrid poplars in the Columbia River Basin in eastern Oregon responded to added nitrogen with increased height and stem diameter growth.

The fast poplar growth reported in Oregon and Washington are likely not achievable in Saskatchewan where the growing season is much shorter, so that nitrogen needs are likely less. In Saskatchewan, the growth rate of hybrid poplar is also limited by soil moisture, light and temperature. However, the northern and eastern regions of agricultural Saskatchewan are suitable for the growth of adapted clones (Schroeder 1999). In suitable sites where adequate water supply is available, hybrid poplars are the fastest-growing trees and therefore likely have the greatest nitrogen requirement. Hybrid poplar wood can be used in pulp, oriented strandboard and lumber or other value-added wood products and has been suggested as an alternative crop (Saskatchewan Forest Centre 2005).

This paper reports on projects done by the AAFC-PFRA Shelterbelt Centre with collaboration from the Prairie Agricultural Machinery Institute (PAMI) to 1) develop a compatible poplar planting design and a swine effluent delivery system 2) assess poplar clones and their response to added nitrogen. The project depended on funding for two Saskatchewan Agriculture Development Fund (ADF) projects and cooperation with partners in industry, university and private landowners listed at the end of this paper.

The results reported here are derived from the ADF projects “Hybrid poplar plantations for farm diversification in Saskatchewan” (Project# 20010048) and “Application of sewage effluent from an intensive livestock operation to hybrid poplar plantings” (Project# 20000259) and from greenhouse research conducted at the Shelterbelt Centre. The data come from poplar alley-crop systems planted in 2002 at Preeceville and Arborfield, SK, poplar clonal test plantations established in 2002 at Star City and Meadow Lake, a fertilized Walker poplar plantation established in 1998 at Henribourg, SK and greenhouse studies at the Shelterbelt Centre.

Materials and methods:

Sites:

(See Table 1)

Preeceville – In 2002, 1440 rooted poplar cuttings were established on a 3.0-hectare site that consisted of a slightly undulating glacial till loam soil with several low spots. The trees were arranged in rows with 10 m alleys between them for machinery access for swine effluent application. Four poplar clones (Walker, CanAm, Hill and Katepwa) were planted in single rows and in double rows which had 3 m between rows. In both the single-row and double-row designs, the trees were planted 2 m apart within the rows. There were four blocks (replicates).

Arborfield – A 3.0-hectare planting was established in 2002 in single rows with in-row spacing of 2 m. The spacing between rows was 6.5 m to allow for machinery access for swine effluent application. The site was on clay loam – loam soil classified as suitable for hybrid poplar growth.

Henribourg – An existing hybrid poplar plantation was used for assessing nitrogen response of older trees. This site located at the Weyerhaeuser Seed Orchard was initially established in 1998 under the Canada-Saskatchewan Agri-Food Innovation Fund with the partnership of Weyerhaeuser Canada and SaskPower. For this study, 16 plots of Walker poplar were selected (four blocks (replicates) X four nitrogen rates) in which each plot consisted of 24 trees (6 X 4) at a spacing of 2.4 m X 2.4 m. Trees in these plots were repeatedly measured over the course of the study.

In addition to the clonal comparison at Preeceville, a large number of poplar clones were also compared in large plots, established in 2002, in two sites at Meadow Lake and one at Star City. At the Meadow Lake (A) site, 15 clones were compared while 12 clones were planted at the Meadow Lake (B) and Star City sites. There were three blocks (replications) at each site. The trees were planted at a spacing of 3.6 m X 2.4 m.

Table 1. Hybrid poplar research sites

Site	Planting year	Test	Area
Preeceville	2002	Alley-crop/effluent	3.0 ha
Arborfield	2002	Alley-crop/effluent	2.9 ha
Henribourg	1998	Block/fertilizer	0.2 ha
Meadow Lake (A)	2002	Block/clonal	1.9 ha
Meadow Lake (B)	2002	Block/clonal	1.3 ha
Star City	2002	Block/clonal	2.1 ha
Indian Head	N.A.	Greenhouse trials	N.A.

Effluent and nitrogen application:

The Prairie Agricultural Machinery Institute (PAMI) truck was originally designed for injection application of swine effluent into the soil at a depth of 11 cm. However, since poplar roots generally grow near the surface of the soil, the truck was adapted by adding an adjustable boom to the rear of the tool bar to allow for the surface application, thus preventing damage to the tree roots. The boom system evenly distributed the effluent over a 3.5 m width and was offset 1.5 m on the driver's side of the truck to allow for application at the base of the trees. The hoses attached to the boom were arranged at the correct angles to deliver the effluent evenly and provide full surface coverage, including an end nozzle that delivered effluent directly to the base of the trees.

On May 18, 2004 and May 11, 2005, PAMI surface-applied swine effluent at the Preeceville site. Swine effluent was taken from the lagoon at the nearby barns using the PAMI truck. Effluent was applied at pre-determined volumes and samples taken from the effluent were sent for analysis with the amount of nitrogen applied per hectare calculated afterwards. These rates are shown in Table 1. In 2004, the actual nitrogen applied was less than expected because the nitrogen concentration in the effluents was unusually low. The 22,500 and 45,000 l/ha rates were each applied in a single pass but the 90,000 l/ha treatment was applied in two passes to avoid runoff.

Table 2. Effluent application rates at Preeceville in 2004 and 2005

Rate		Nitrogen (kg/ha)	
(l/ha)	(gal/acre)	2004	2005
0	0	0	0
22,500	2,000	12	45
45,000	4,000	24	90
90,000	8,000	47	180

At the Arborfield site, the PAMI truck was used to successfully apply swine effluent to the poplar trees at a rate of 90,000 L/ha (50 kgN/ha) in June, 2004 and July, 2005.

At the Henribourg site, granular nitrogen, applied as ammonium nitrate (33-0-0), was applied at four different rates (0, 50, 100,150 kg/ha) to the selected Walker poplar at the site. The fertilizer was applied using hand spreaders by making several passes over the plots. The same rates were applied in 2001, 2003 and 2004.

Greenhouse nitrogen uptake studies:

In a greenhouse study of nitrogen uptake, four hybrid poplar clones (Hill, Katepwa, Walker and WP69) were grown from cuttings in sand culture to which nitrogen was added in various proportions of nitrate (NO_3^-) and ammonium (NH_4^+). The cuttings were monitored for nitrogen uptake and growth for a two-month period.

Data collection:

Preeceville – Soil nitrogen (NH_4^+ and NO_3^-) was measured before and after effluent application at 0-30 cm and at 30-60 cm depths. Tree height and diameter at breast height (DBH) were measured before and after the effluent application in 2004 and 2005. Soil samples were taken before and after effluent application to monitor soil nitrogen. Soil was sampled at two depths (0-30 cm and 30-60 cm) and was taken from each plot at two points and bulked into one sample for each depth. Leaf samples were taken for total nitrogen analysis in August of 2004 and 2005 by collecting the 6th leaf from the end of the main shoot from each of six trees in each plot. The leaf samples were bulked by plot and then dried, ground and analyzed for total nitrogen.

Arborfield – The treated and untreated trees were measured for height and DBH in October, 2005.

Henribourg – Soil nitrogen was measured before and after fertilizer application at 0-30 cm and 30-60 cm depths. Also measured were the total height and the height increase of the trees, and the ratio of the height increment to total tree height (expressed as percent) and the diameter at breast height (DBH). Only the centre eight trees of each plot were measured. Soil samples were taken before application and each fall after the growing season was complete. Soil at two depths 0-30 cm and 30-60 cm was taken from the centre row of each plot at 3 points and bulked into one sample for each depth. Leaf samples were taken each year in August collecting the 6th and 12th leaf from each of the eight measured trees. The leaf samples were bulked by plot and leaf number. Both the soil and leaf samples were dried, ground and sent to a laboratory for nitrogen analysis.

Meadow Lake and Star City – In the large block clonal trials, the height of 25 trees per plot was measured in October, 2005 for each clone in each replication. At the same time, one representative tree in each plot was cut at ground level in October, 2005 and the total biomass was determined.

Greenhouse nitrogen uptake studies – Measurements of the rooted poplar cuttings in the greenhouse included total biomass production, the rate of nitrogen uptake (total and by nitrogen form) and the final nitrogen contents in the aboveground shoot (not including the leaves).

Results:

Swine effluent application effects:

At Preeceville, soil nitrogen increased after effluent (Figures 1, 2) and most was in the form of nitrate (NO_3^-). Soil nitrate levels depended on the rate of effluent added. There were no differencse in soil nitrogen levels by poplar clone treatment.

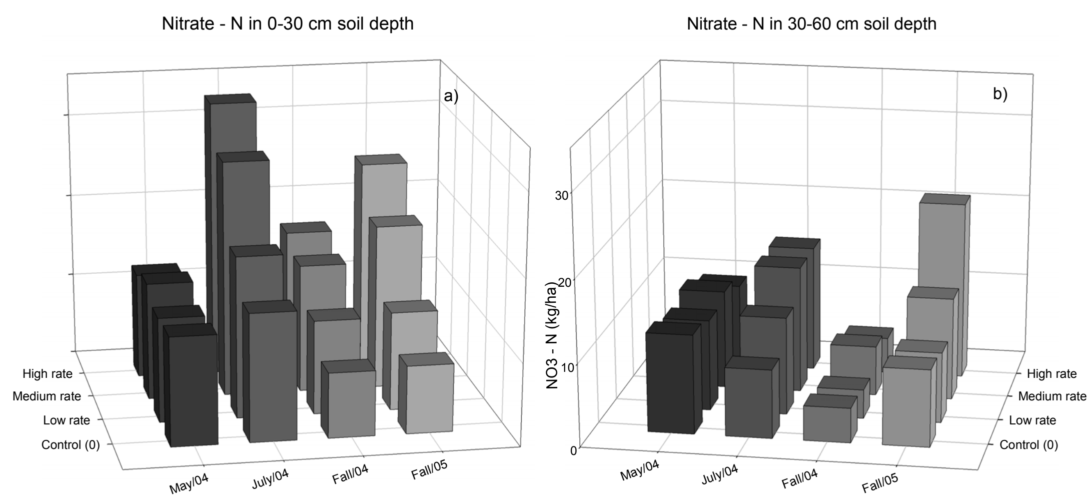

Figure 1. Nitrate nitrogen in soil before and after effluent application.

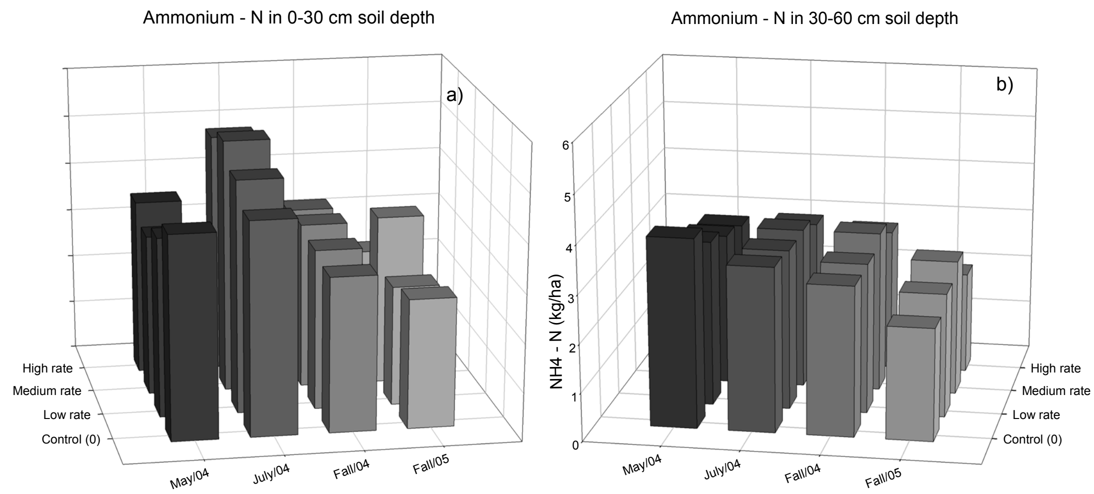

Figure 2. Ammonium nitrogen in soil before and after effluent application.

By the fall of 2005, effluent application rates had no significant effects on the growth of the poplar trees at Preeceville but there were some clones that responded positively and some that responded negatively to the effluent application at Arborfield. At Preeceville, the average tree heights for different treatments varied from 261 to 275 cm, while a difference of over 20 cm would have been needed to show significant differences at the 5% level. There were also no significant differences in stem diameter at breast height (DBH) for the different effluent application rates. At Arborfield, the applied effluent resulted in significant tree height increases in the clones WP69 (11%) and Katepwa (7%) and significant decreases in Assiniboine (12%) and CanAm (7%).

Fertilizer effect on Walker poplar at Henribourg:

The 2003 and 2004 fertilizer applications increased the soil nitrogen levels at the 0-30 cm and the 30-60 cm depths (Figure 3). By the fall of 2005, soil nitrogen levels were similar to those measured before the 2003 fertilizer application.

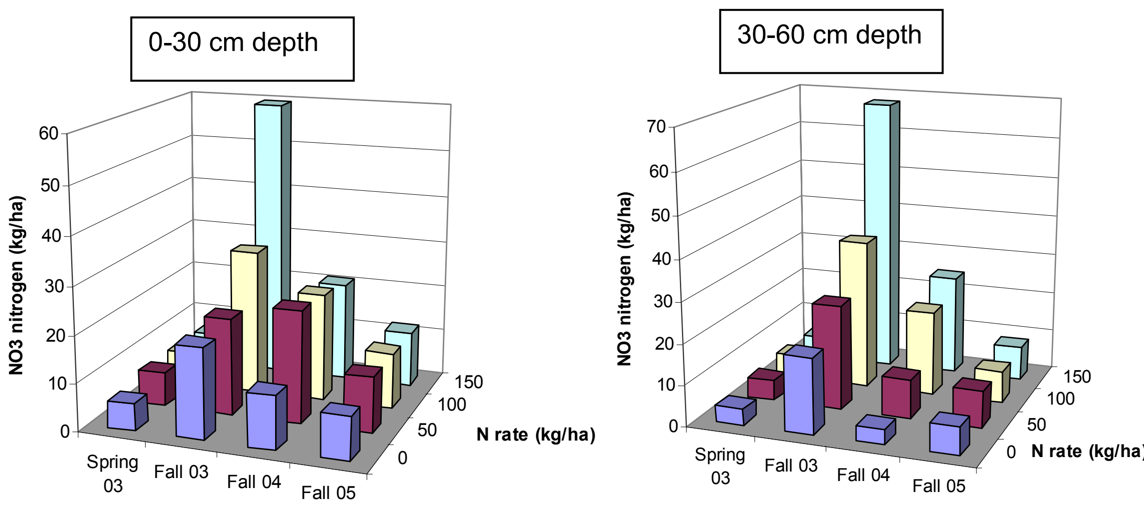

Figure 3. Measured soil nitrogen before and after fertilizer application in spring of 2003 and 2004.

In the 2001-2005 growing seasons, there was no significant response of the final height of the Walker poplar to added nitrogen fertilizer. The average final height in the fall of 2005 was 7.4 m (Figure 4) and the DBH average was 8.7 cm. Neither growth indicator showed a significant response to the fertilizer rate. The overall average height of the Walker poplar showed a general trend of top dieback from one year to the next as seen by the downturns in the lines in Figure 4. The new growth for 2003-2005 showed an increase in response to the nitrogen rate (Figure 5) even though there was no effect in the final tree height.

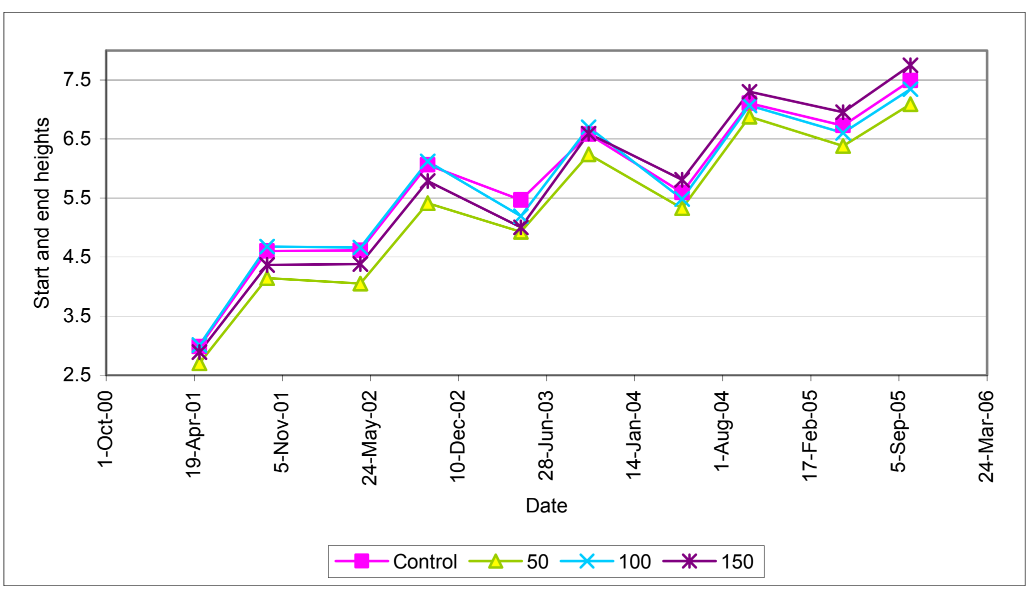

Figure 4. Height increase of Walker poplar at Henribourg (2001-2005)

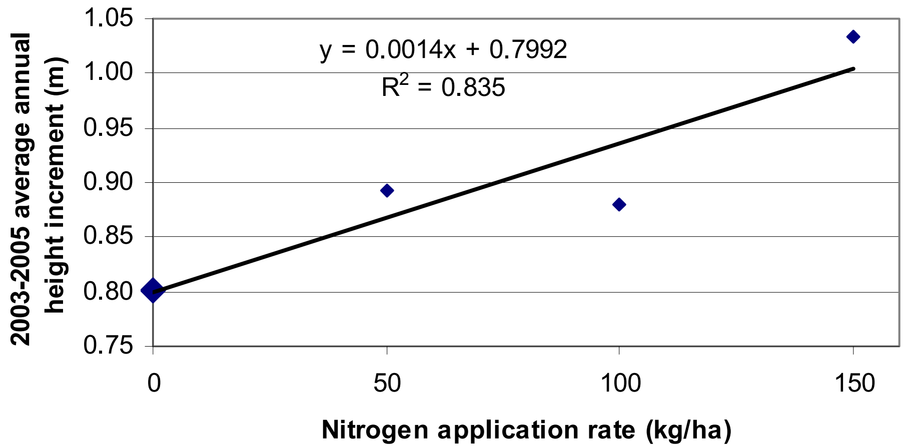

Figure 5. The height increments of the main shoots of Walker poplar in response to added nitrogen fertilizer. The annual shoot increments for the years 2003, 2004 and 2005 were averaged.

Leaves collected in 2003 from rapidly-growing shoots from the top whorl of branches had variable nitrogen concentrations and there was a linear relationship between leaf total nitrogen content and the growth of the terminal shoot in 2003 (Figure 6) although leaf nitrogen did not vary significantly as a result of the amount of nitrogen applied.

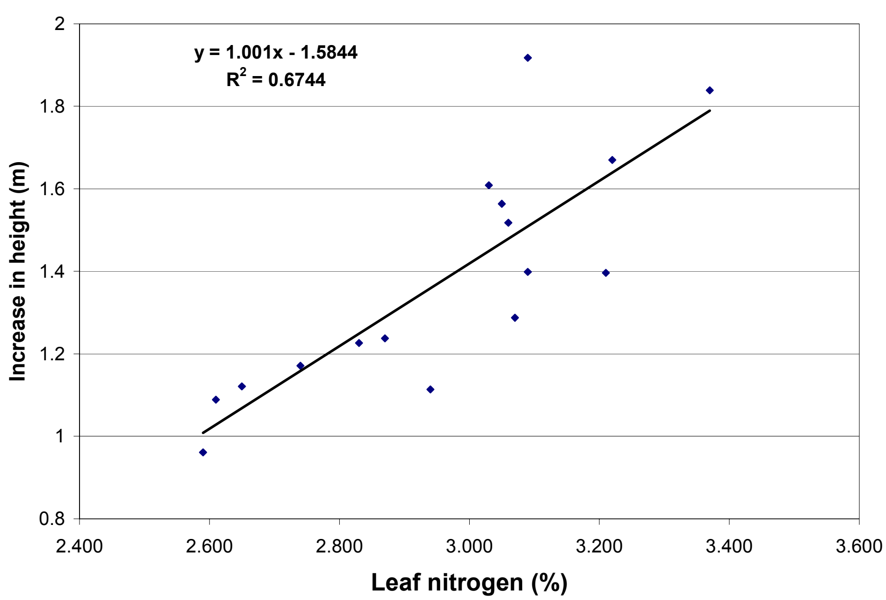

Figure 6. Correlation of leaf nitrogen in the 6th leaf with the height growth of the terminal shoot in Walker poplar trees at the Weyerhaeuser site in Henribourg (2003 results).

Clonal comparisons:

In the Preeceville planting where only four clones were compared, the final height of the Katepwa and Walker poplar was greater than for Hill and CanAm poplar by the fall of 2005 (Table 3). Katepwa and Walker poplar also showed greater annual height increments. The pattern for DBH was similar, although the Katepwa and Hill were not significantly different from each other. For all measurements, however, Walker grew significantly faster than CanAm poplar.

Table 3. 2004 and 2005 height and diameter growth and final height and diameter of four hybrid poplar clones. Within any column, different letters after the numbers indicate that the clones are significantly different at the 5% level.

	Height (cm)			Diameter (mm)	
	Increment		Final	Increment	Final
Clone	2004	2005	2005	2005	2005
Walker	81 a	105 a	308 a	16.7 a	29.1 a
Katepwa	74 b	104 a	274 b	13.6 b	24.8 b
Hill	52 c	90 b	246 c	12.5 b	21.5 b
CanAm	55 c	75 c	222 d	8.3 c	13.8 c
Average	66	93	263	12.8	22.3

The ratio of height growth to DBH growth was highest in the CanAm poplar, indicating that these trees were more spindly than the other clones. Estimated biomass, based on a calculation from the trees' diameters and heights was greatest for Walker poplar. It was estimated that the Katepwa poplar had an average of about 70% of the biomass of Walker poplar compared to only 20% for CanAm. Even for the Walker poplar, the aboveground dry biomass was not estimated at higher than 2 kg. Hill poplar was notable for its branchiness which could represent a substantial amount of biomass so, although its height and diameter were less than Walker and Katepwa, its biomass by 2005 was likely similar to that of the Katepwa poplar.

There were significant clonal differences since the leaves of CanAm poplar consistently had higher leaf nitrogen across treatments and in 2004 and 2005 (Table 4). The average nitrogen concentration in the CanAm poplar leaf tissue was 7% greater than Katepwa, the clone with the lowest nitrogen.

Table 4. Percent nitrogen in the leaves of four poplar clones at Preeceville. In the "Average" column, different letters after the numbers indicate that the clones are significantly different at the 5% level.

Clone	Nitrogen (% of leaf dry weight) 2004	2005	Average
CanAm	3.56	3.08	3.32a
Hill	3.41	3.06	3.24b
Walker	3.41	3.02	3.22b
Katepwa	3.21	2.98	3.10c
Average	3.40	3.04	3.22

In the clonal tests at the Meadow Lake A, Meadow Lake B and Star City sites, there were major clonal differences and the relative performances of the four clones that were used at Preeceville were similar. Early growth data suggest that WP-69 and Katepwa are well adapted clones with above average growth rates compared to other clones in the test (Figure 7).

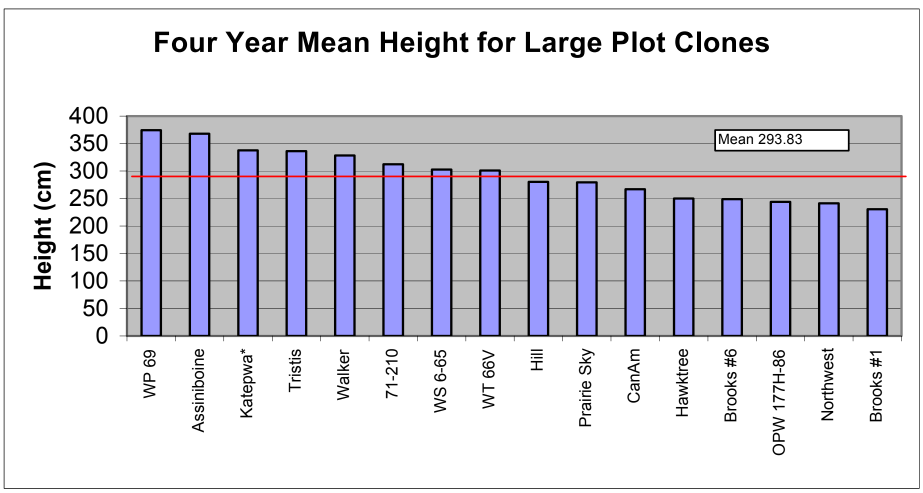

Figure 7. Final height after four years for 16 clones at Meadow Lake and Star City. The red bar represents the overall average.

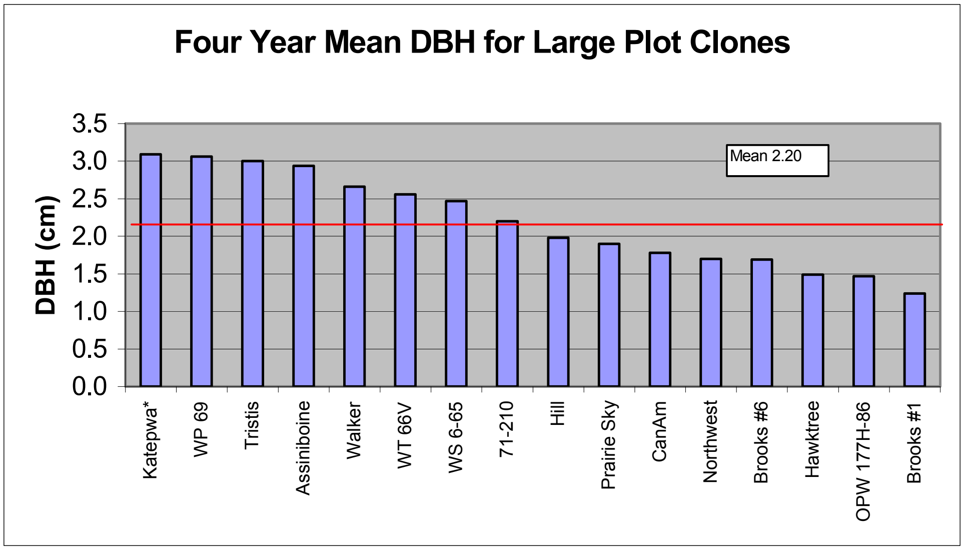

Figure 8. Final DBH after four years for 16 clones at Meadow Lake and Star City. The red bar represents the overall average

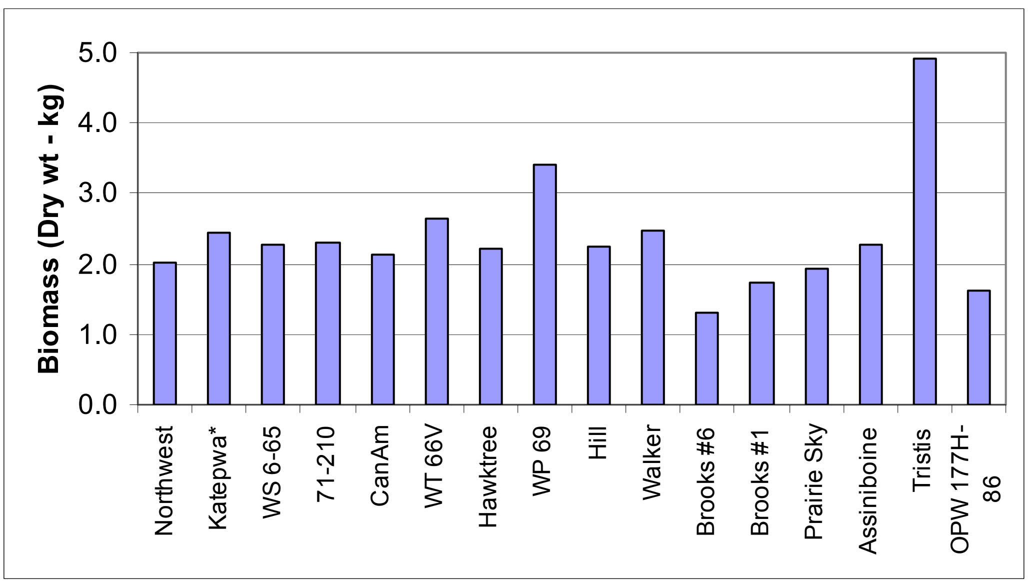

Figure 9. Final biomass after four years for 16 poplar clones at Meadow Lake and Star City

In the greenhouse study, Walker and WP69 showed a greater nitrogen uptake capacity than the other two clones (Figure 10). However, when the relative preference of the clones for nitrogen forms was compared, the Hill and Katepwa poplar took up a greater proportion of their nitrogen in the NH_4^+ form. The percentage of nitrogen in the tissues of Hill and Katepwa was also greater.

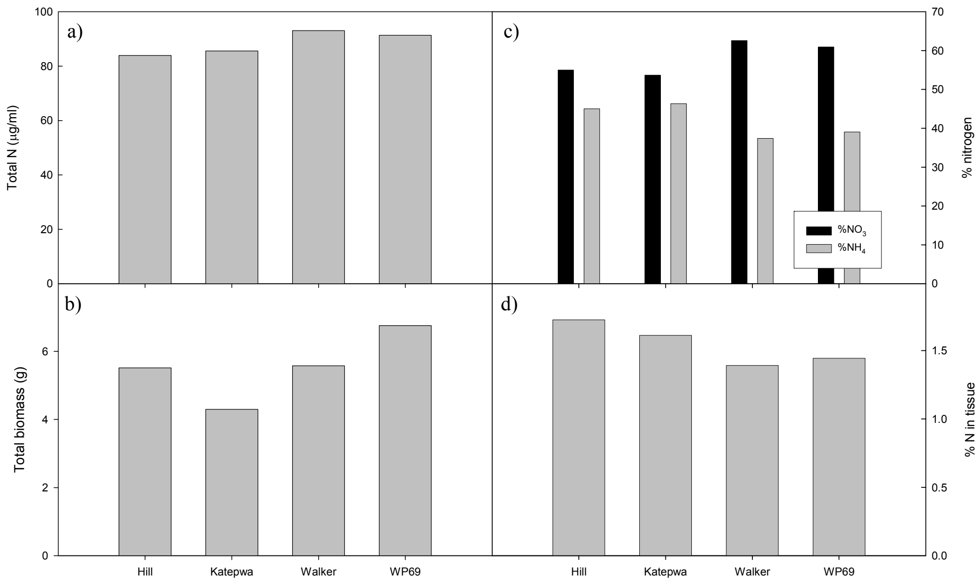

Figure 10. Nitrogen uptake characteristics of four hybrid poplar clones. a) The total nitrogen taken up from the nutrient solution b) The total biomass, aboveground and belowground c) Relative percent uptake of NH_4^+ and NO_3^- d) Nitrogen concentration in the tissue.

Discussion and conclusions:

The research sites that were developed under the ADF projects at Meadow Lake, Star City, Arborfield and Preeceville and earlier plantings such as the one at Henribourg, represent an important resource for on-going and future poplar research in Saskatchewan. For the 2002 plantings, weed control and weather made establishment a challenge but, by the end of 2005, the trees were generally about 3 metres in height. At this size, the trees were too small to take up significant amounts of nitrogen.

Added nitrogen, in the form of swine effluent, did not result in increased tree growth at Preeceville but at Arborfield, the two clones WP69 and Katepwa showed growth increases of 11% and 7%, respectively, in response to the addition of 50 kgN/ha. Walker poplar did not respond to swine effluent at the Arborfield test, the Preeceville planting or in the Henribourg site in which trees planted in 1998 had achieved complete crown closure and an average height of 7.4 m by the fall of 2005. These results suggests clonal differences in the ability to respond to added nitrogen and that WP69 and perhaps Katepwa may be better suited for sites where high nitrogen availability is anticipated compared to Walker poplar, a clone shown to be fast-growing and adapted to Saskatchewan conditions.

The greenhouse study showed that Katepwa and Hill poplars used a greater amount of nitrogen per unit of biomass compared to Walker and WP69 and, although all four clones had greater uptake rates for NO_3^- than for NH_4^+, Katepwa and Hill had relatively higher rates of NH_4^+ uptake than the other two clones. The greater biomass of WP69 poplar compensated for the lower tissue concentration of nitrogen to give high overall nitrogen uptake while the Hill poplar combined moderate biomass with higher nitrogen concentration in the tissue and a greater ability to take up NH_4^+. Based on these results, it appears that there are clonal differences in nitrogen uptake, tissue nitrogen concentration and preference for nitrogen form. It appears that Hill poplar may be of special interest in sites where the NH_4^+ levels are greater such as sites in which swine manure is applied.

The clones Walker, Katepwa and WP69 were also among the better-performing clones found in the clonal tests conducted at Meadow Lake and Star City. All of these sites have had only four growing seasons and early growth may not necessarily relate well to long-term performance. Several clones such as Hill, Northwest and Brooks#6 may have great long-term growth potential. Even in the fourth year, the Hill poplar trees at Preeceville appeared to have a greater leaf area and crown spread than Katepwa.

The nitrogen cycle for trees is often a complex process because, in addition to new soil nitrogen from fertilization, nitrogen is recycled from leaf litter and within the tree by nitrogen repartitioning from old, structural tissues (wood) to the growing tissues (bark, new wood, twigs and leaves). The nitrogen needs, even of intensively-managed poplar plantations, are thus not clear and there is a wide range of nitrogen recommendations. Conservative recommendations of 50 kgN/ha/yr have been given in other regions and are similar to crop nitrogen requirements.

The development of alley-cropping research plots in association with swine barns at Preeceville and Arborfield will be useful for future study and monitoring in this area. The design of these plantings is appropriate to the application of effluent from PAMI’s truck delivery system in which the modified boom is able to apply the effluent uniformly and efficiently to the tree root zone.

References:

Breuer, D. W., Cole, D.W. and Schiess, P. 1977. Nitrogen transformation and leaching associated with wastewater irrigation in Douglas-fir, poplar, grass, and unvegetated systems. *In:* Municipal Wastewater and Sludge Recycling on Forest Land and Disturbed Land. *Ed. by:* W.E. Sopper The Pennsylvania State University Press, University Park, Pennsylvania.

Hansen, E.A. and Baker, J.B. 1979. - Biomass and nutrient removal in short rotation intensively cultured plantations. Proceedings of the Annual meeting - North American Poplar Council. Thompsonville, Michigan 1979. p.130-51.

Hansen, E.A. and Tolsted, D.N. 1985. Nitrogen sources and fertilizer rates affect growth of hybrid poplar. The Fifth Central Hardwood Forest Conference. Proceedings of a meeting held at the University of Illinois at Urbana-Champaign, Illinois April 15-17, 1985.

Heilman, P.E. and Stettler, R.F. 1986. Nutritional concerns in selection of black cottonwood and hybrid clones for short rotation. Canadian Journal of Forest Research. 16: 860-863.

Saskatchewan Forest Centre. 2005. Saskatchewan-Grown Hybrid Poplar for Veneer Products and Oriented Strandboard. Technical Sheet Series # 2002/06. Accessed from: www.saskforestcentre.ca/uploaded/techsheet200206skgrownhp.pdf 2 pp.

Schroeder, W.R. 1999. Determination of poplar wood quality and land suitability. Canada-Saskatchewan Agri-Food Innovation Fund Project 960000472 Final Report 20 pp.

Strand, R.F. 1986. Fertilization of irrigated hybrid poplar in north-central Oregon. IEA/ENFOR/OMNR Joint Report. Pp. 165-174.

Stanturf, J.A., van Oosten, C., Netzer, D.A., Coleman, M.D. and Portwood, C.J. 2001. Ecology and silviculture of poplar plantations. *In:* Poplar Culture in North America. Part A, Chapter 5. Ed. by: D.I. Dickmann, J.G. Isebrands, J.E. Eckenwalder and J. Richardson. NRC Research Press, National Research Council of Canada. Ottawa, Ontario pp. 153-206.