Fiber-to-fiber—a case study at Domtar, Cornwall

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ABSTRACT: Domtar Inc., at its pulp and paper mill in Cornwall, Ontario, Canada, has developed a unique program for handling mill process residues. The mill accomplished an about-turn from landfilling to recycling by implementing a comprehensive land application program for the beneficial use of residuals, including pulp and paper mill biosolids (PPMB) on land.

Positive results from agronomic research in using PPMB—dewatered effluent treatment residue—to improve agricultural soils and boost grain and forage production are now well established. Five years of data collected from operational plantations of short rotation tree species are now showing the benefit of using pulp and paper mill residues. The results show a good potential for the use of process residues, particularly PPMB, in a kind of closed loop recycling that returns wood-based residues to the forest to grow more wood fiber; from fiber back to fiber.

Application: The use of pulp and paper mill residuals to grow more trees is a largely unexplored benefit of papermaking. Land application of mill residues is silviculturally beneficial, economically sensible, ecologically sustainable, and environmentally responsible.

The Canadian pulp and paper industry generated an estimated 7.1 million metric ton of solid residues in 1995. The main materials involved were wood and bark (60%), pulp and paper mill biosolids (PPMB) 23%, inorganic residues (12%), and miscellaneous (5%) [1]. According to a Pulp and Paper Research Institute of Canada (PAPRICAN) review, mills landfilled or burned 88% of all PPMB. Only 7% were recycled by means of land application. A follow-up survey conducted by PAPRICAN in 2001 [2] indicated that while all the mills had some form of primary and/or secondary treatment, 61% had activated sludge treatment (AST) and were therefore generating secondary or combined (primary plus secondary) biosolids. These mills have a daily disposal requirement: landfilling, incineration, or land application. The survey showed that 51% of the mills with (AST) biotreatment practiced land application. Half of the 20 mills reporting land application applied more than 95% of their biosolids. Most of the PPMB was used on agricultural land (70%); only a little (4%) was used in silvicultural land. Land rehabilitation accounted for the balance (26%).

The experience at the Domtar mill in Cornwall, Ontario, Canada, follows the industry pattern. In the early 1990s, all of the process residues, amounting to 125,000 to 150,000 metric tons per year, were landfilled. However, a change in methods and attitude was needed because new landfill space was difficult to acquire [3]. Consequently, the Cornwall mill now landfills only 3% of its residues, with 80% being land applied and the balance sold or otherwise recycled. All of the mill's Combined PPMB is land applied (**Table I**).

Year	Generated	Sold	Recycled	Land Applied	% Diverted
1994	110	0	2	9	11
1995	137	6	18	75	72
1996	128	10	3	95	84
1997	97	13	1	76	93
1998	122	16	6	96	97
1999	124	20	4	97	97
2000	126	20	4	95	95
2001	147	20	5	117	97
2002	123	18	3	93	92

I. Diversion from landfilling to beneficial use, Cornwall mill; all solid waste in thousands of metric tons (as is basis).

Since 1994, 597,000 metric tons of residues of the million metric tons generated by the Cornwall mill have been land applied. Included in this total are 407,000 metric tons of PPMB. Over the period, 78% of all residues have been used on agricultural land and only 19% have been used in silviculture. Specifically, 84% of the PPMB have been used on agriculture and only 14% in silvicultural projects (**Table II**).

Efforts to divert mill residuals from landfilling first involved the use of primary PPMB as a mulch on a company owned plantation of hybrid poplar (*Populus euro x americana*). This initial work showed a good potential for silvicultural land application [4]. However, difficulties with scheduling and logistics in delivery and spreading materials on-site favored the development of agricultural applications. The inauguration of secondary (AST) treatment at the mill in 1995 resulted in a new type of PPMB—a mix of primary and secondary treatment solids called "Combined PPMB." Combined PPMB has a greater value as a soil amendment and organic fertilizer than primary treatment biosolids. Cornwall mill PPMB has an organic carbon content double that of livestock manure, while having an attractive carbon-to-nitrogen ratio of 20:1. It has a total nitrogen content of 1.8%-2.0% and is similar to solid manure in nitrogen nutrient content. It is therefore also similar in its value and potential use (**Tables III and IV**).

Agricultural Applications

Because of its similarity to solid manure, acceptability to cash crop (corn) farmers, availability of suitable land base, easier logistics, and the necessity to move large volumes (200-300 wet metric tons/day); the land application of the mill's PPMB initially focused on agriculture.

All solid waste in thousands of metric tons (as is basis)					
Product	Combined PPMB	Primary PPMB	Lime	Wood Products	Total
Agriculture	344 (84%)	11 (30%)	110 (100%)	—	465 (79%)
Silviculture	55 (14%)	14 (37%)	—	42 (97%)	123 (18%)
Rehabilitation	8 (2%)	12 (33%)	—	1 (3%)	2 (3%)
TOTAL	476	37	137	43	693

II. Land application – Cornwall mill, delivery to agriculture, silviculture, land rehabilitation by material, January 1, 1994-December 31, 2002.

Parameter	Domtar Combined PPMB (Jan. to Dec. 2002)	Compost Livestock Manure (May 1995 to Sept. 1997)
% Solids	34.3	43.5
% Organics	82.4	53.6
% Ash	17.6	46.4
C:N	22.6	11.4
pH	7.4	8.9
Nitrogen (TKN) (ppm)	17,833	10,273
Total phosphorus (ppm)	3150	5800
Potassium (ppm)	1195	23,000
Source	Effluent Treatment Plant–Domtar (Cornwall)	Kemptville College of Agricultural Technology–Manure Storage Facility
Composition	47% cellulose fiber 32% microbial cells 21% clay and calcium carbonate	Livestock Manure

III. Domtar Combined PPMB compared to composted manure.

Nutrient	[1] Fall Application (kg/ha)	[2] Spring Application (kg/ha)	Total Available to Crop (kg/ha)	Total Equivalent Value (CAD/ha)	Value per wet metric ton (as is)
Nitrogen	50.2	150.06	200.3	182.27 [a]	CAD 2.20
Phosphate	25.8	38.7	64.5	56.79 [b]	CAD 0.68
Potassium	11.9	17.85	29.75	13.69 [c]	CAD 0.16

[1] Based on an application rate of 10 dry metric ton (equivalent) per hectare. [2] Based on an application rate of 15 dry metric ton (equivalent) per hectare. [a] Price based on local cost of urea = CAD 420.00/metric ton – Spring 2001 (cost of urea and spreading). [b] Price based on local cost of phosphate: (MAP) = CAD 405.00/metric ton. [c] Price based on local cost of potash: 0-0-60 = CAD 278.00/metric ton. NOTE: Value of organic matter content not included.

IV. Nutrient value of Domtar Combined PPMB compared to agricultural inorganic fertilizer.

PPMB are considered processed organic waste under the Ontario Environmental Protection Act. The provincial ministry of environment must certify and approve all sites receiving PPMB. Operations must be conducted according to ministry guidelines. Approval is contingent on the safety of the materials being land-applied in terms of "protecting land productivity, food quality, consumer and animal health, and environmental quality … In essence, these materials must be of benefit to crop production or soil health, before approval for use will be given …" [5].

First year test plots conducted in cooperation with the then Ontario Ministry of Agriculture proved the agronomic benefit of PPMB, facilitating approval for initial projects. A subsequent annual research program conducted by the University of Guelph has continued to provide the scientific rationale for the agricultural aspect of the mill's land application program [6]. Currently, the agricultural program is well established with bi-annual application to more than 50 farms.

Silviculture Applications

Domtar controls 55,000 hectares of forestland for the supply of wood fiber to the Cornwall mill. Of this area, 2000 hectares (ha) located close to the mill are plantations of hybrid poplar and silver maple (*Acer saccharinum L.*). These fast growing species are established on marginally productive, formerly agricultural land and managed in short rotations. Rotation age for these two species is approximately 15 years for the poplar and 35 years for the maple. Rapidly grown deciduous trees, especially hybrid poplar, are very demanding of site fertility. Control of competing vegetation in the early establishment phase is also important. Repeated whole tree harvesting of hybrid poplar plantations without replacement of nutrients and biomass through fertilization or use of soil amendments can reduce site productivity in subsequent rotations.

Given the ready availability of PPMB and other organic residuals, such as bark and wood waste from mill operations, two operational silvicultural treatments were developed using these materials. The two treatments are mulching and fertilization. PPMB can be used the same as mulch and fertilizer. Implementing these treatments required the following components: application rates; placement of materials; equipment capable to economically transport and spread large volumes of materials in both pre- and post-tree establishment situations; application techniques; and timing of applications [7].

Mulching and Fertilization

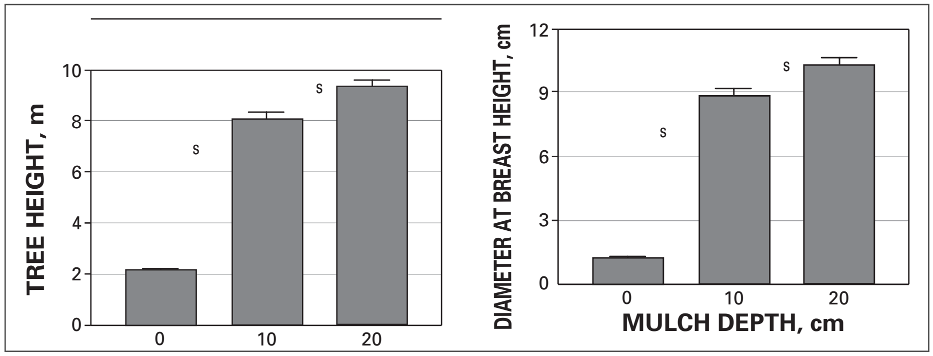
Mulching trials were initiated in 1992. Primary PPMB, applied at rates of up to 424 dry metric tons/ha (20 cm thickness) in replicated plots planted with hybrid poplar, showed beneficial weed control and positive growth response. Environmental monitoring data—soil and ground water parameters—were collected and analyzed for 5 years [8, 9]. No detrimental environmental effects were detected. Tree growth response data collected over 9 years continued to show positive effects compared to control (**Figure 1**). This replicated, detailed, and closely monitored trial provided the basis for subsequent operational mulching treatments used in other hybrid poplar and silver maple plantations.

Operational mulching now uses a mix of bark or primary clarifier fiber with Combined PPMB in a one-time application. The materials are applied in strips at a rate of 110 dry metric tons (equivalent) per hectare. Mulching can be an addition to, or an alternative to, standard mechanical and chemical site preparation before planting tree cuttings or seedlings. Mulching can also be used in established plantations.

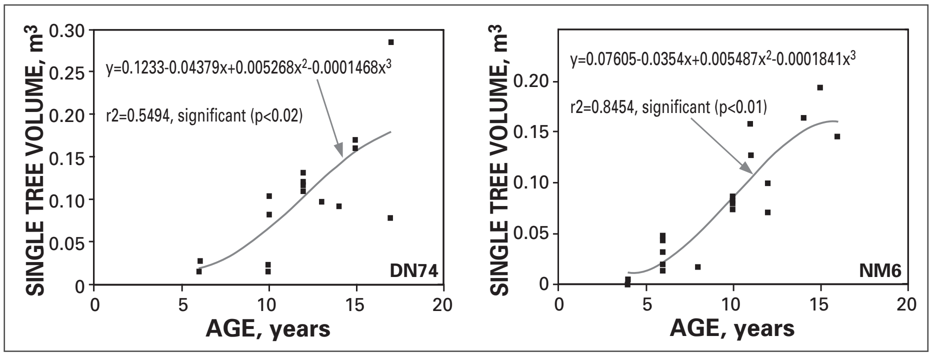
Likewise, fertilization treatments can occur before or after tree establishment, with a maximum annual application of 25 dry metric tons/ha of Combined PPMB. In fertilization treatments, only Combined PPMB are used. The Combined PPMB are broadcast and subsequently incorporated into the soil surface using a light disking, as opposed to mulching, which leaves the materials on the soil surface. Fertilization may be applied annually, including the year before planting as part of site preparation.

Since 1995, 708 ha have been mulched or fertilized with mill residues (**Table V**).

The regulatory necessity of proving a benefit from the use of PPMB applies equally to silviculture application as it does for agricultural uses. Formal operational mulching trials and informal field observations of fertilizer treatment have shown positive response by young trees to applications of PPMB as mulch and particularly fertilizer applications. However, hard data are needed to prove positive yield response to support continued use. Yield response for multi-year silvicultural crops is more difficult to document than for annual agricultural crops because volume yield prediction using growth data collected from very young trees are not reliable.



1. 1994 Osnabruck mulch trial; height and diameter at age 9 years.



2. Standard single tree volume by age curves.

	Mulching Primary/Bark and PPMB @ 110 dry metric tons/ha equiv. (30% consistency)		Fertilization * PPMB @ 25 dry metric tons/ha equiv. (30% consistency)	
	Hectares	Metric tons (as is basis)	Hectares*	Metric tons (as is basis)
1995	3	1000	0	0
1996	110	32,900	57	4900
1997	32	12,900	10	800
1998	50	17,500	35	2900
1999	37	13,800	32	1900
2000	17	3700	59	4700
2001	7	2200	114	8900
2002	3	1400	142	10,900

* includes repeat applications

V. Silvicultural land application of PPMB, Domtar Cornwall mill.

Sample sites

In 1997, three company owned production plantations were selected as study sites. The three sites had been mulched or fertilized in 1996 (**Table VI**). Representative sample trees in treated and untreated areas were chosen and subsequently measured annually to determine tree growth response to the particular treatment as compared to nearby untreated areas. Where non-treated areas did not exist near the site, other non-treated plantation blocks with trees of the same clone, age, and soil type were used as comparison. Plantations with the standard production hybrid poplar clones DN74 and NM6 were chosen. Additional sites were added in the following years and sampled annually (Table VI a and b).

Where possible, non-treated areas adjoining treated areas served as controls. One hundred trees were selected, starting four rows of trees in at each side of the treatment/non-treatment boundary. All trees were numbered consecutively and 10 sample trees were chosen randomly. The 10 sample trees were marked and measured annually. Two measurements were taken: total height and diameter at breast height. Data were collected in 1997, 1998, 1999, 2000, 2001, and 2002 and statistically analyzed using student "t" tests.

Year-over-year differences in height and diameter growth and volume growth (a function of change in height and diameter) were also determined each year. Treatment and control samples were compared to each other and compared to standard single tree volume-by-age curves. These curves (**Figure 2**) were constructed using regularly collected plantation assessment data for clones DN74 and NM6 in the company's production plantations.

RESULTS AND DISCUSSION

Fertilization Treatment

Hybrid poplar, particularly when grown in short rotation, are demanding of site nutrients. Nitrogen is usually the limiting nutrient for maximum growth performance. Combined PPMB from the Cornwall mill average a total nitrogen content of 1.9%. Almost all of this nitrogen is in slow release organic form. An estimated 40% becomes available in the year of application through biological decomposition in the soil. An application of 25 dry metric tons/ha (equivalent) of Combined PPMB can provide 200 kg/ha of available nitrogen for tree growth. This rate of nitrogen application is similar to

Site/ Location	DOMTAR 22 Control	DOMTAR 22 Treatment	DOMTAR 23 Control	DOMTAR 23 Treatment	TFA 45 Control	TFA 45 Treatment
Soil Type	Grenville Loam	Grenville Loam	Grenville Loam	Grenville Loam	Eamer Loam (Bouldery Phase)	Eamer Loam (Bouldery Phase)
Species/Clone	Hybrid Poplar NM6	Hybrid Poplar NM6	Hybrid Poplar DN74	Hybrid Poplar DN74	Hybrid Poplar DN74	Hybrid Poplar DN74
Planting Stock	Cuttings	Cuttings	Cuttings	Cuttings	Cuttings	Cuttings
Date Planted	1993	1993	1993	1993	2000	2000
Tree Spacing	3 m x 3 m	3 m x 3 m	3 m x 3 m	3 m x 3 m	2 m x 5 m	2 m x 5 m
Tree Age at Application	3 and 6 years	3 and 6 years	3 and 6 years	3 and 6 years	0	0
Years Sampled	1997 through 2002	1997 through 2002	1997 through 2002	1997 through 2002	2000 through 2002	2000 through 2002
Materials Used	NA	Combined PPMB	NA	Combined PPMB	NA	Combined PPMB
Rate Applied	0	25 dry metric tons/ha	0	25 dry metric tons/ha	0	25 dry metric tons/ha
Date Applied	NA	July 1996, Feb. 1998	NA	July 1996	NA	Sept. 1999, June 2001

VI a. Growth Studies Summary - Fertilizing.

Site/ Location	TFA 16 / TFA 98 Control	TFA 16 / TFA 98 Treatment	TFA 19 * / TFA 23 Control	TFA 19 * / TFA 23 Treatment	DOMTAR 78* Control	DOMTAR 78* Treatment
Soil Type	Kars Gravelly Sandy Loam	Kars Gravelly Sandy Loam	Sandy Loam	Sandy Loam	Osgoode Loam	Osgoode Loam
Species/Clone	Hybrid Poplar NM6	Hybrid Poplar NM6	Hybrid Poplar NM6	Hybrid Poplar NM6	Silver Maple	Silver Maple
Planting Stock	Cuttings	Cuttings	Cuttings	Cuttings	Rooted 2+0	Rooted 2+0
Date Planted	1996	1996	1998	1998	1989	1989
Tree Spacing	3 m x 3 m	3 m x 3 m	2.5 m x 3.7 m	2.5 m x 3.7 m	2.5 m x 2.8 m	2.5 m x 2.8 m
Tree Age at Application	0	0	0	0	8 years	8 years
Years Sampled	1998 through 2002	1998 through 2002	1998 through 2002	1998 through 2002	1997 through 2002	1997 through 2002
Materials Used	NA	Combined PPMB	0	Combined PPMB @ 55dry metric tons/ ha and Bark @ 55 dry metric tons/ha	0	Primary PPMB @ 55dry metric tons/ ha and Combined PPMB @ 55 dry metric tons/ha
Rate Applied	0	110 dry metric tons/ha	0	110 dry metric tons/ha	0	110 dry metric tons/ha
Date Applied	Spring 1996	Spring 1996	Spring 1998	Spring 1998	Summer 1996	Summer 1996

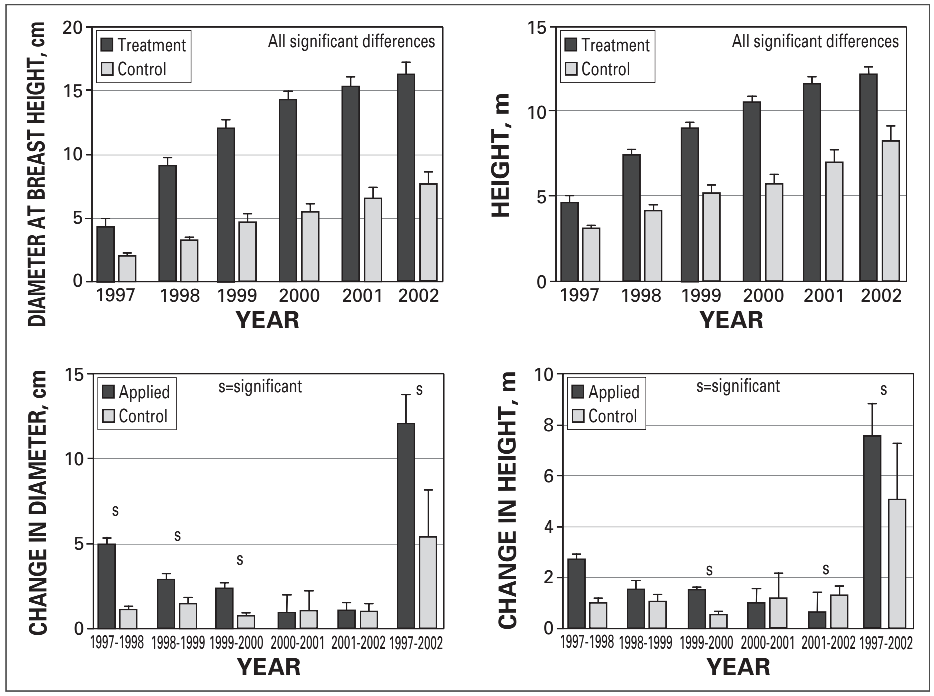
* Fertilized in 2001

VI b. Growth Studies Summary - Mulching.

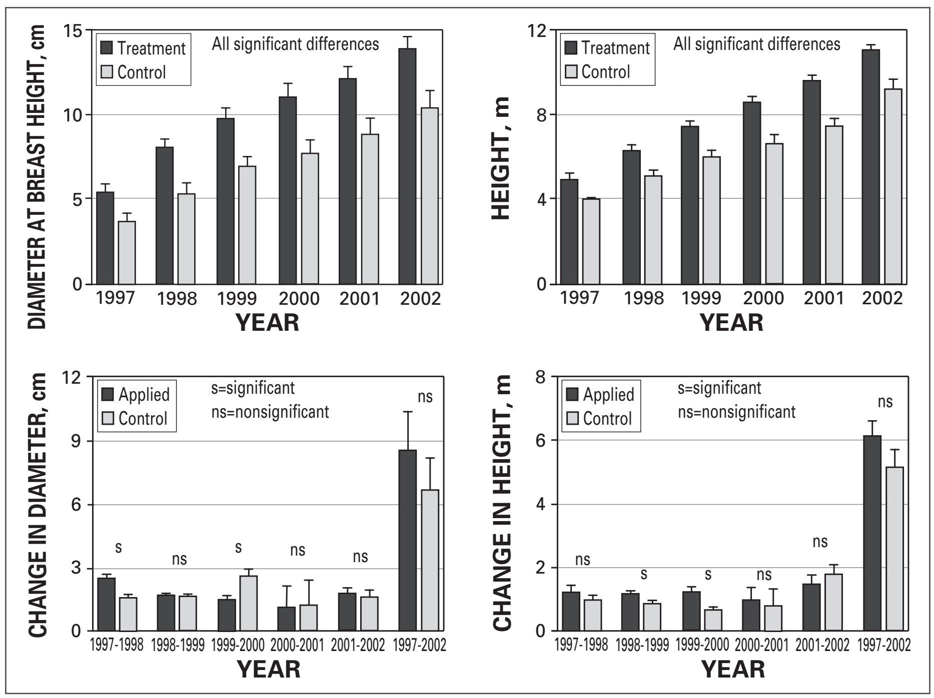
rates of commercial inorganic nitrogen that may be otherwise applied in the company's hybrid poplar plantations as a silvicultural treatment to promote growth. However, application of commercial inorganic nitrogen is considered uneconomical.

Applications of PPMB are typically made according to the agronomic requirement of the plant species grown on the site. This implies that the amount of the PPMB-supplied nitrogen matches the requirements of the vegetation for growth. This effectively removes the restriction to increased growth from limited soil nitrogen availability. Traditional silvicultural fertilization regimes of inorganic fertilizers involve one or two fertilizer applications through the rotation. They cannot supply the amount of nutrients required at the rate needed during the exponential phase of tree growth. Under these conditions, organic fertilizers can often be of benefit, providing a more gradual release of nutrients. Application rates, however, need to be based on the capability of the biological system for nutrient uptake. Estimates of nitrogen uptake by hybrid poplar are dependent on clone, plantation density, and tree age [10]. Van Ham (2001) [11] in a municipal (sewage) biosolids fertilization rate trial applied up to 4000 kg of nitrogen per hectare (as total nitrogen) without significant leaching losses of nitrogen. On the basis of this research, Van Ham calculates the agronomic application rate of municipal biosolids for intensively managed hybrid poplar trees to be between 1800 kg and 2000 kg total nitrogen per hectare.

Fertilizing treatments using Combined PPMB have been used at the Cornwall mill since 1995 (Table V). The hybrid poplar clone NM6 on site Domtar 22 and clone DN74 on site Domtar 23 were both treated with 25 dry metric tons/ha of Combined PPMB in the summer of 1996 at age 3 years; and again in February of 1998 at age 5 years. Clone DN74 planted at site TFA 45 in 2000 was fertilized with Combined PPMB the year before planting (1999) and in 2001 and 2002. All three plantations were second rotation plantations, meaning that the site had already produced one crop of fiber. **Figures 3-5** show consistent significant differences in the annual increase in diameter and height of the treated versus untreated trees. The results for NM6 on site Domtar 22 are dramatic, possibly because this is a very productive clone capable of responding to favorable site conditions. When comparing tree volume at age 10 years, fertilized NM6 hybrid poplar contain 7 times the volume of their unfertilized controls (70.1 m^3/ha vs. 9.1 m^3/ha) and 1.34 times the volume indicated by the standard growth curve for this clone at this age (**Fig. 6**). Similarly, Clone DN74 fertilized trees contain more than twice as much volume as the controls (64.4 m^3/ha vs. 37.1 m^3/ha), but have a volume comparable to that indicated by the standard volume curve for DN74 (**Fig. 7**).



3. Growth response to fertilization; 25 dry metric tons/ha Combined PPMB, 1996 and 1998 (Domtar 22).



4. Growth response to fertilization; 25 dry metric tons/ha Combined PPMB, 1996 and 1998 (Domtar 23).

Data collected for the Domtar 22 and Domtar 23 plantations in 2002 showed that growth in treated plantations is slowing down relative to previous years. This is likely due to no new fertilization treatments having been made since 1998. Height and growth differences between treated and untreated trees in the young TFA 45 plantation of clone DN74 that has been fertilized annually since 1999 (year 2000 excepted) shows consistent significant differences in height in 2000, 2001 and 2002.

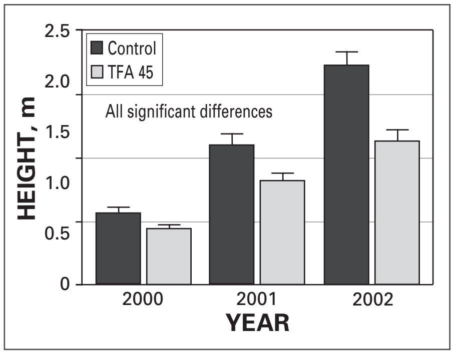
It is expected that positive growth response can be maintained, if not accelerated, as these plantations mature and receive regular applications of PPMB as fertilizer. The use of PPMB as fertilizer in tree plantations is economical since the material is surplus and the company must incur an expense in order to land apply the material in any alternative use such as agriculture.

Mulching treatment

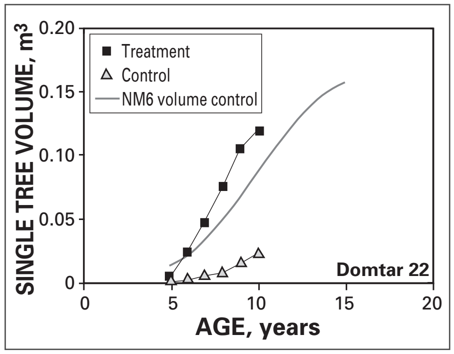
Any benign material used in a surface application to soil to protect plants from competing vegetation and soil moisture loss is a mulch. Ideally, mulch should biodegrade, build up the soil, and provide nutrients to the crop plants as it degrades. PPMB is such a material, either by itself or combined with other organic residues, such as bark. Domtar has used mill organic residues, including bark, primary PPMB, and Combined PPMB, to help establish or tend established production plantations of hybrid poplar and silver maple since 1997 (Table V).

This study compared tree growth in mulched areas to growth in unmulched areas of the same plantation. In some cases, unmulched plantations on other similar sites (comprised of the same species/clone of the same age having had similar management) were used as controls. Site TFA 98 received 110 dry metric tons/ha (equivalent) of Combined PPMB laid in 1.5 m wide strips at 3 m spacing before planting cuttings of hybrid poplar NM6. **Figure 8** shows the difference in total height and diameter growth between the treated site and a comparable untreated site. **Figure 9** shows the significant difference in tree volume as compared to the control and the standard volume curve for NM6. Comparing volumes, the treated trees carry 15 times the volume of the controls (69.8 m^3/ha vs. 4.6 m^3/ha) and 2.8 times the volume indicated by the standard curve at age 7 years. The dramatic difference may result from the combined effects of weed control and fertilization.

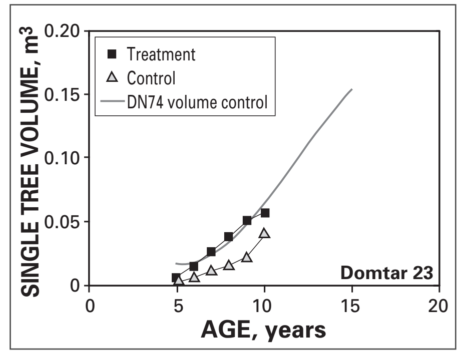
Site TFA 19 used a mulch comprised of 55 dry metric tons/ha (equivalent) of Combined PPMB applied in rows, as in TFA98, but with an additional 55 dry metric tons/ha of bark layered over the rows for additional weed suppression effect. Comparing the growth results, there was no significant difference in growth between the treated plantation at age 3 years (2000) and the untreated plantation (**Fig. 10**). However, after an application of PPMB as fertilizer in June of 2001, the data collected in 2001 indicated a positive change in both diameter and height growth, although differences were not statistically significant. This plantation was again fertilized in 2002 using 25 dry tonnes (equivalent) per hectare of Combined PPMB. In 2002 diameter, height and volume were larger at the treated site versus the control. Only height was significantly larger.



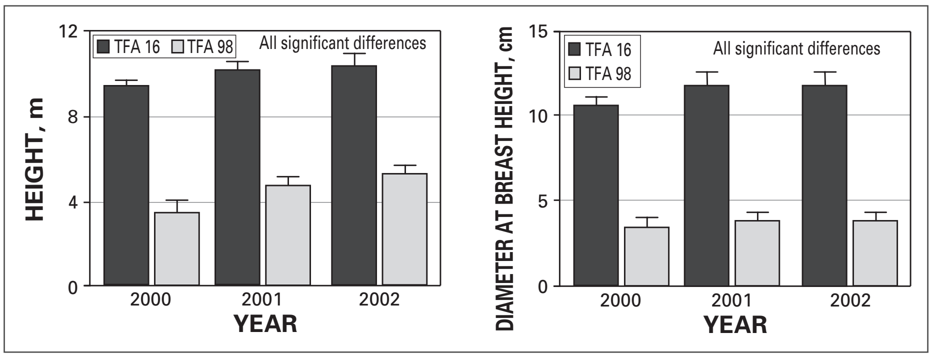
5. Growth response to fertilization; 25 dry metric tons/ha Combined PPMB, 2000 and 2001 (TFA 45).



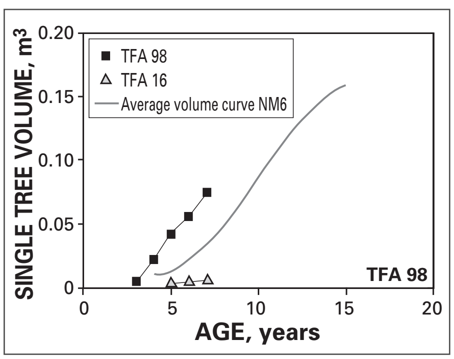
6. Volume growth response to fertilization; 25 dry metric tons/ha Combined PPMB, 1996 and 1998.



7. Volume growth response to fertilization; 25 dry metric tons/ha Combined PPMB, 1996 and 1998.



8. Growth response to mulching; 110 dry metric tons/ha Combined PPMB in 1996 (TFA 98).



9. Volume growth response to mulching; 110 dry metric tons/ha Combined PPMB in 1996.

Volume per hectare was similar for the two sites (11.6 m3/hectare vs 9.9 m3/hectare). The differences in all parameters are increasing. The initial lack of difference between control and treatment could be explained by the amount of bark used in the mulch; causing less nutrients to be available to the trees, which was then corrected by the additional PPMB fertilizer treatment in 2001 and 2002. The two plantations are also not comparable because of differences in actual row spacing. The trees in the treated stand have a much wider actual spacing than their nominal three meter by three meter spacing.

Site Domtar 77 is a silver maple plantation treated with a mixture of 55 dry metric tons/ha (equivalent) of Combined PPMB and 55 dry metric tons/ha of primary PPMB. This mulch treatment was applied alternately between the rows when the trees were 8 years old. **Figure 11** shows that there was no significant effect of the mulch in terms of growth over the four years (to 2000) of measurements other than in height growth in the first year. The site was fertilized with Combined PPMB in the summer of 2001 and the trees responded positively (Fig, 11; 2001).

The fact that the mulch was not incorporated into the soil and that nutrients were not available to the trees—having been tied up by the low nutrient primary clarifier fiber—is a possible explanation for the initial lack of response. This explanation appears to be borne out by the results after fertilization in 2001 and 2002. Treatment trees had a greater diameter and height growth (Fig. 11) in 2002 as a response to the added fertilizer. Because the trees were also well established at age 8 years at time of treatment, with a more or less closed canopy and little competing vegetation, the mulch weed control effects may have been superfluous. Data from 2002 show significantly larger diameters and heights at the treated versus the control site, resulting in a volume of 142.8 m3/ha vs. 120 m3/ha.

CONCLUSIONS

Silvicultural applications of pulp and paper mill (combined) biosolids to fertilize production hybrid poplar plantations at environmentally appropriate rates have a significant positive effect on potential yield. A 100% increase in total wood fiber yield may be projected, based on data from fertilized, but as yet immature plantations.

Other organic pulp and paper mill residues, such as bark, can be used with Combined PPMB as mulches. The effect of mulching on yield is unclear; there is no significant positive or negative yield effect evident from the current results. Fertilizer treatments added to mulching appear to increase growth. There are cost advantages from using mill residues as mulches instead of using standard chemical and mechanical site preparation and initial stand tending inputs. Fiber-to-fiber, the use of mill residuals generated from processing of trees into pulp and paper to grow more trees is a largely unexplored benefit for the pulp and paper industry. Land application is silviculturally beneficial, economically sensible, ecologically sustainable, and environmentally responsible. **TJ**

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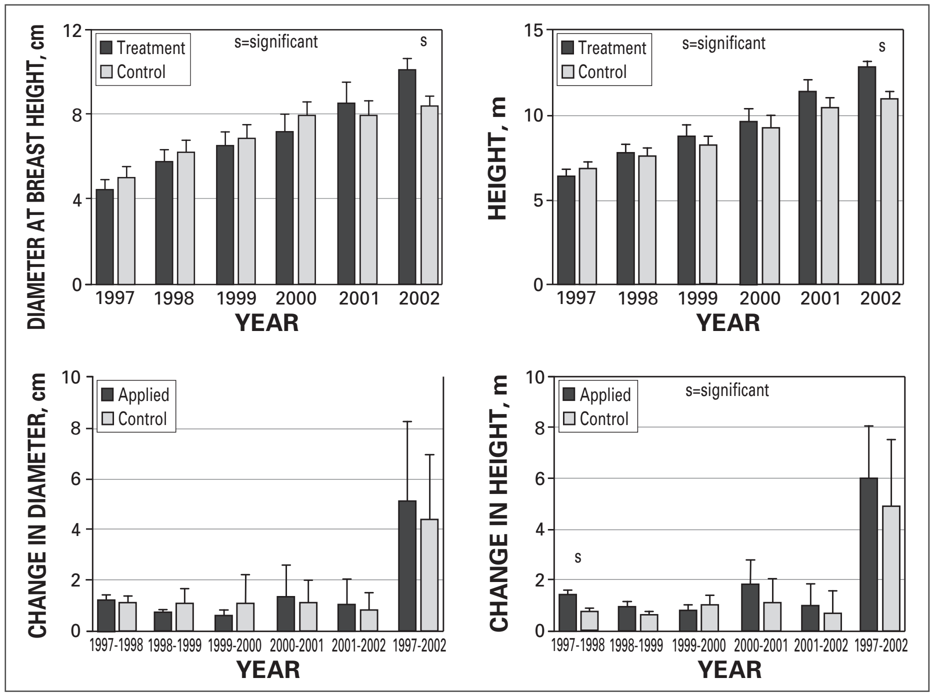
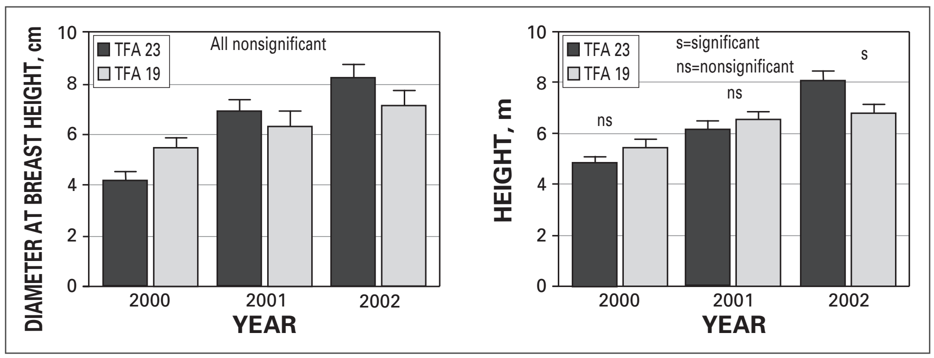


10. Growth response to mulching and fertilizing; 55 dry metric tons/ha of bark + 55 dry metric tons/ha of Combined PPMB in 1998, fertilized with 25 dry metric tons/ha Combined PPMB in 2001 (Domtar 77).



11. Growth response to mulching and fertilizing; 55 dry metric tons/ha of primary PPMB mixed with 55 dry metric tons/ha of Combined PPMB in 1996, fertilized with 25 dry metric tons/ha Combined PPMB in 2001 (TFA 19).

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INSIGHTS FROM THE AUTHORS

We chose this topic to research because it has potential for direct benefit to our mill. This work tracks operational plantations which have been treated using pulp and paper mill biosolids based on information from previous experimental research.

Setting up statistically valid comparisons in an operational field situation proved to be a challenge. One of the most interesting findings of our work is the degree of response to fertilization with organic nutrient.

Other mills can use the information we've presented to save on residue disposal cost, to reduce silvicultural costs, and to increase fiber yield. The next step is to continue tracking representative stands to rotation age to determine final yield.

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