High biomass production by *Salix* clones on SRIC following two 3-year coppice rotations on abandoned farmland in southern Quebec, Canada

Michel Labrecque *, Traian I. Teodorescu
Institut de recherche en biologie végétale, Jardin botanique de Montréal, 4101 Sherbrooke East
(Montreal) Quebec, Canada, H1X 2B2
Fax : 514-872-3765, michel_labrecque@ville.montreal.qc.ca

Our research team has been involved in projects of intensive cultures of willow on short rotations since 1989. Various experiments were done to find ways to maximize yield by keeping costs to a minimum. More recently, diverse experiments were conducted on large cultured areas in the south of Quebec province (Canada) on abandoned farmlands with different soil conditions. Annual yields were from 10 to 15 tons of dry biomass per the hectare. At the end of the first three years of growth, best results were obtained with two willow species: *Salix viminalis* L., identified by the Forest Ministry of Quebec as clone 5027, and *S. discolor* Mühl. harvested from natural stands in the Upper St. Lawrence region.

The main objective of this study was to follow up the development and the yield of large surfaces of intensive culture of these two species of willow during their second cycle of growth (1998-2000). More specifically, we aimed to compare the growth performance and nutrients exported by willow species cultivated on extensive marginal sites with different soil characteristics and to assess the impact of fertilization with wastewater sludge on yields after a second rotation cycle (six years after establishment).

Methods

Experiments were conducted on two sites in the different edaphic conditions (a sandy site and a clay site), located in the Upper St. Lawrence region about 90 km southwest of Montreal. The climate of this area is continental, and is characterized by a 182-day frost-free period and 2106 degree-days (above 5^0 C). Average annual temperature is 6.4^0 C and mean annual precipitation is 954 mm, i.e. 767 mm of rain and 187 mm of snow. Mean total precipitation during the growing season (from May to September) calculated over a period of 21 years (1961 to 1990) is 427 mm.

In fall 1997, willows cultivated on two large (10 000 m² each) experimental plots were coppiced and the aerial biomass was harvested. The following spring, a new 6-block split-split plot was designed on each site. Each block of 1666.6 m² was divided into two plots of 833.3 m² (fertilization treatments), each of which was again divided into two sub-plots (416.6 m²) according to the two species cultivated in the field. The doses of sludge applied in spring 1998 for each treatment were calculated on the basis of the theoretically available nitrogen content for the first year of application (inorganic N + 0.30 organic N) determined per kg dry matter (DM) of sludge. Treatments equivalent to 100 (T1) and 0 (T0) kg of "available" N per ha were used. These doses were obtained by applying 20 and 0 t (DM) of sludge per hectare.

Measurements of growth were taken for each plot on six randomly chosen plants for each species fertilization treatment and block. At the end of the 2000 growing season, the same plants were coppiced and weighed in the field with a spring scale. To evaluate the dry matter of biomass, green stem samples were taken from the field and oven-dried at 70°C (to constant mass) before being weighed. Productivity (t ha^{-1}) was calculated taking into account plantation densities and dry matter of biomass. Stem element concentration and content were determined from a sample of stems taken on the two plantation sites from plants of both species in November 2000. All the data were subjected to variance analyses (ANOVA), followed by multiple comparisons of means according to Tukey's method.

Results

At the end of November 2000, the growth performance (height, diameter and biomass productivity) of willows planted on the clay site was better than that of willows on the sandy site. Plants of *S. viminalis* were significantly higher than those of *S. discolor*. The sludge fertilization induced a significant increase of height growth of *S. viminalis*. For both species, the growth in diameter was higher on the clay site compared to plants grown on the sandy site. On the two plantation sites, the stem diameter of *S. viminalis* was significantly higher than that of the other species. Sludge fertilization positively affected the growth in diameter of *S. viminalis*. After three growing seasons, *S. discolor* developed a significantly greater number of stems than *S. viminalis*. However, the fertilization treatment did not affect this number. For both species, greatest productivity was obtained on the plots of the clay site. This productivity varies according to the fertilization treatment. Thus, on the fertilized plots of the two sites, *S. viminalis* produced more biomass than *S. discolor*. On the non-fertilized plots of the sandy site, the productivity of the two species was comparable. Sludge application had a significant effect on the two sites but only for *S. viminalis*. The best dry mass production was obtained by the fertilized plants of *S. viminalis*. Effects of sludge application on biomass production were more apparent on the sandy site, which was poorer in nutrients than the clay site.

The 70 tons obtained at the end of the second rotation cycle by *S. viminalis* on the fertilized plots of the clay site show the exceptional yield of this species on Canadian lands. The biomass productivity of *S. discolor* was not affected by fertilization. The yield of 31.48 tons per hectare represents only 43.3 % of the biomass obtained by *S. viminalis* under the same conditions.

The content in elements in the exported biomass (stems and branches) could indicate the nutritional needs for willows in SRIC. A long term fertilization plan of could consider replacement of nutritive elements which are exported with the biomass harvested. This study shows that in the fertilized plots of the clay site *S. viminalis* needed 528.5 kg nitrogen in order to produce 70.36 tons of dry mass. The elements exported from the soil by the two species (in kg per ton of dry mass harvested) are: N from 5.3 to 7.5; P from 0.6 to 0.9; K from 1.8 to 3; Ca from 4.2 to 7.2 and Mg from 0.4 to 0.7.

Conclusions

The results of our experiments show that willows in SRIC prefer seasons rich in precipitation (especially during May and June) and fresher temperatures. The clay site was more favorable to the growth and development of willow. On this site, an impressive quantity of dry biomass of 70 tons per hectare (20.2 t the first year, 17.9 t the second year and, 32.3 t the third year) was produced in the fertilized plots of *S. viminalis*.

Wastewater sludge constitutes a good fertilizer for willows under SRIC. Our results suggest that a moderate dose of sludge (about 20 tons of dry matter per hectare (100 kg of N "available") could have a positive impact on the economic profitability of biomass production with reduced environmental risks. However, this dose seems insufficient to meet the needs of willows for several seasons, especially on sandy soil where resources are insufficient.

A long term program of fertilization plan should take into account the replacement of exported elements from the soil by the biomass harvested. For a production of 20 tons of dry biomass per hectare, *S. viminalis* in SRIC would need some 150 kg of nitrogen, 18 kg of phosphorus and 60 kg of potassium.