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Pig slurry as fertilizer on willow plantation

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ABSTRACT

The aim of this study is to investigate the effect of the use of pig slurry as fertilizer on the productivity of a willow plantation, while evaluating the risk of a negative impact on the environment. We evaluated plant response to increasing slurry amounts and compared this response to the effect of mineral fertilization. We also verified the impact of slurry on soil nutritional content as well as on nitrate and phosphorus concentrations in the soil. Although slurry nitrogen was less efficient than mineral fertilizer, the results of our study show that slurry constitutes an effective fertilizer for willow plantations. In fact, yields over two years on plots that received increasing amounts of slurry were on the order of 30.0–32.9 t/ha. We observed an increase in soil levels of nitrates, copper and zinc as a function of increasing slurry amounts. These levels actually decreased during the second growing season, possibly due to uptake by the willows. Springtime concentrations of water in lysimeters indicated that the maximum quantity of slurry tested was accompanied by a certain risk of nitrates leaching into the soil.

1. Introduction

The intensification of agricultural activities, characteristic of production farms in many regions of North America, often has an undesirable environmental impact. Intensive pig farming, which implies high animal density per unit of surface area, often results in difficulties to manage the slurry generated. One of the main strategies to manage this waste is to reuse it in agriculture. However, the application of slurry to crops can lead to an excess of nutrients and a consequent leaching into the surrounding environment. Several studies have demonstrated a relationship between excessive slurry application and increased nitrogen (N) and phosphorus (P) levels in water bodies [1–3]. This nutrient enrichment of water bodies causes imbalances in aquatic ecosystems, such as eutrophization and cyanobacterial proliferation. Surplus nitrogen in the soil can also leach into ground water, and consequently lead to contamination of the water table by nitrates (NO_3-N) [4–7]. Other studies have noted significant accumulations of copper (Cu) and zinc (Zn) (metals added to pig fodder) in soils, following excessive application of slurry [8–10].

In order to better manage this situation, maximal application norms have been established in many countries often in respect of provincial or state regulations. With the frequent results that producers, who often lack sufficient area for spreading slurry, accumulate a surplus that is increasingly difficult to contain.

Recycling pig effluent in short rotation intensive culture (SRIC) of fast growing willows may constitute an ecological and economical alternative method for manure treatment. The high biomass yield which characterizes willows, associated with high nutritional and water requirements [11,12], would theoretically allow the use of large quantities of slurry as fertilizer, while limiting nutrient loss to the surrounding

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environment. The highly developed root system of willows [13] not only takes up water and nutrients efficiently, but can also reduce percolation, and hence the risk of leaching elements to the water table [14]. Thus slurry application on a willow plantation in SRIC can both supply economical fertilizer for plant production which represents new sources of income to producers, as well as a reduction of the area required for animal waste disposal.

Recycling organic waste on willow plantations is an avenue that has been frequently used during the last few years. Because they contain essential nutrients for plant growth, organic residues are an economical source of fertilizer for willow plantations, which have particularly high nutrients requirements [11]. In addition to ensuring the productivity and durability of the plantation, the utilization of these residues in some cases implies reduced costs for waste treatment [15]. Consequently, several studies have examined the use of recycled municipal wastewater and sludge in fast growing willow plantations [16–20]. Experiments in Quebec have demonstrated two to three fold increases in biomass production following the application of dried sludge equivalent to 100–300 kg of N/ha [21–23].

Furthermore, few studies have examined the effects of recycling animal waste on willow plantations. One specific study has shown the advantages of using the fertilizing values of livestock residues on such crops [24]. In this trial, the biomass yield of a willow plantation increased from 30 to 38% following fertilization with chicken manure (100–300 kg N/ha). While fertilization with pig slurry is a common agricultural practice, in the context of a perennial woody crop it is rare. Only recently Lteif *et al.* [25] conducted a study on poplar hybrids fertilized with pig slurry. In this case, the application of slurry equivalent to 116 and 233 kg of N/ha/year induced an increase in biomass of 3.84 and 5.20 t/ha over two years.

The objective of the present study is to measure the effect of using slurry as fertilizer on the productivity of a willow plantation, while evaluating the risks of a negative impact on the environment. To highlight the effects of applying increasing quantities of slurry on the plantation and the environment, a comparison was made with effects of mineral fertilization. To this end, we i) studied and compared the effect produced by slurry and mineral fertilizer on biomass yields as well as on nutritional uptake by willows, ii) verified the impact of slurry on the nutritional status of the plantation soil and iii) evaluated the impact of fertilization with slurry versus mineral fertilizer on concentrations of nitrates and phosphorus in the soil solution.

2. Materials and method

2.1. Description of the experimental site

The experiment was conducted on a willow plantation located in Saint-Roch-de-l'Achigan in the Lanaudière region of Quebec, Canada (45° 50′ 50" N - 73° 38′ 27" W). The region has a continental climate characterized by an average annual temperature of 5.3 °C and 1018 mm of precipitation. The 2008 and 2009 growing seasons (beginning of May to end of September) were characterized by similar average temperatures (17.0 °C and 16.4 °C respectively) that were close to the normal (16.7 °C). Total precipitation during the first growing season (373 mm) was lower than in 2009 (445 mm) and lower than normal (454 mm) for the time of year [26].

The experiment was conducted on a *Salix miyabeana* (clone SX67) plantation, established in SRIC in May 2007 with a density of 16,000 plants ha^{-1} (35 cm between plants and 1.8 m between rows) on a surface area of 0.45 ha. SX67 was chosen because it is one of the most productive cultivars currently used commercially in Canada and in the US [27]. Willow growth and development were excellent during the establishment year (2007), with a survival rate above 95% at the end of this growing season. Plants were coppiced during the winter of 2007–2008, according to common practice and in order to promote growth and development of new stems. The various fertilization treatments were applied at the beginning of June 2008.

2.2. Experimental design

The experiment followed a randomized complete block design of 3 blocks with 8 treatments consisting of 4 increasing amounts of slurry, 3 increasing amounts of nitrogen in mineral form and a control with no nitrogen content. The quantities of nutrients supplied by the different treatments are presented in Table 1. Mineral fertilizer nitrogen was applied at 100, 200 and 300 kg N/ha; a range of N doses covering expected optimum N rate for willow [24]. Each plot was 5.4 m in width and included three rows 20 m long. A buffer zone of 3 m (without treatment) separated each of the 20 m long plots at their extremities. Pig slurry was applied using a spreader equipped with a tool bar and three flex drop hoses to gravity-apply manure. The manure was then superficially buried the following day (less than 24 h later) using a harrow, in order to reduce loss of ammonia nitrogen (NH3-N) through volatilization. Slurry samples were taken during spreading in order to determine its chemical composition, presented in Table 2. Pig slurry rates (30–120 m3/ha) brought 148, 295, 443 and 590 kg N/ha; a range of N doses slightly higher than expected, due to a higher N concentration in pig slurry (4.92 g/kg), compared to reference values for Québec (3.5 g/kg).

Table 1 – Quantities of nutrients added to soil by different fertilization treatments.

Treatment	Dose applied (kg/ha)		
	N	P	K
F0: Control	0	26	50
Pig slurry			
F1 (30 m^3/ha)	148	32	75
F2 (60 m^3/ha)	295	64	150
F3 (90 m^3/ha)	443	96	225
F4 (120 m^3/ha)	590	127	300
Mineral fertilizer			
F5	100	26	50
F6	200	26	50
F7	300	26	50