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Effect of dairy effluent on the biomass, transpiration, and elemental composition of *Salix kinuyanagi* Kimura

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ABSTRACT

The land treatment of Dairy Effluent (DE), comprising urine and faeces is common practice, yet can lead to nutrient imbalances in plants and soils. We aimed to determine the growth, transpiration, and elemental composition of *Salix kinuyanagi* Kimura (Clone No. PN 386) as affected by DE application. DE was applied for 15 weeks to eighteen 122 dm^3 lysimeters, either bare or planted with *S. kinuyanagi*, at N application rates of 0–558 kg ha^{-1} over three months. DE application increased biomass and transpiration. Chlorosis, possibly caused by excess Cl, appeared in the highest treatment. DE application increased foliar concentrations ofN, P, K, Cl, and the foliar N:S ratio to above 15, a level indicative of S deficiency. Concentrations of essential trace elements were unaffected. Trees receiving the N equivalent of 279 kg ha^{-1} removed similar amounts of N and K as were applied in the DE. All DE treatments added more Cl than the plants removed. Soil chloride accumulation may be harmful in drier climes. Future work should include a field trial to determine the long-term sustainability of DE application to willows, and the potential use of willows as animal fodder.

1. Introduction

Dairy production, and the housing of cattle during winter, results in large volumes of nutrient-rich dairy effluent (DE), comprising urine, faeces and possibly chemicals used to cleanse the milking or stabling area [1]. Typically, DE contains high concentrations of ammonium-N, P, K, dissolved organic carbon (DOC) and pathogens, such as *Enterococcus faecalis* [2]. Disposal of the untreated DE into waterways is illegal in most countries because the contents may present a human health risk and can induce eutrophication of rivers and lakes [1]. Disposal of the DE in the conventional sewerage system or installing an onsite aerobic or anaerobic treatment ponds can be expensive and may not be effective. Therefore, the application of DE onto land, normally pasture, either raw or after preliminary treatment [3], as an N-rich fertiliser has become commonplace [4]. DE application to pasture significantly enhances plant growth [5]. However, the long-term application

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of DE results in the accumulation of K in the topsoil and reduces the concentrations of Ca and Mg in pasture, which may possibly lead to deficiencies of these elements in grazing animals [5].

DE may also be applied to trees. Roygard et al. [6,7] demonstrated, using a lysimeter study, that the willow clone *Salix kinuyanagi* Kimura, could maintain nitrate concentrations in the drainage water below the New Zealand Drinking Water Standard of 11.3 g NO_3–N m^{-3} when irrigated with DE containing the N equivalent of 870 kg ha^{-1} over two years, more than twice the rate permitted by law. Numerous studies in North America and Northern Europe showed that sewage sludge and other effluents could be applied to willow plantations for biomass production [8–12]. Although willows can mitigate nitrate leaching from DE application, there is a lack of information on effect of various DE application rates on the growth and transpiration of willow.

Potentially, willow biomass produced in the treatment of DE may be fed to stock. Willows are used extensively in New Zealand as supplementary stock fodder during times of drought [13]. Douglas et al. [14] demonstrated that both foliage and small twigs of *S. kinuyanagi* are palatable for cattle. Robinson et al. [15] showed that *S. kinuyanagi* accumulated high concentrations of the essential animal nutrients Co, Fe, Mn, and Zn relative to pasture. The willow leaf Zn concentrations were >140 mg kg^{-1}, some seven times higher than that of pasture growing in the same soil.

The high concentration of DOC in DE may enhance trace element solubility in soils [16]. However, trace elements that are complexed with DE may be unavailable for plant uptake [17]. The application of DE to soil may therefore reduce the uptake of beneficial trace elements by willows. Accumulation of cations, such as K, in the root zone may compete with trace elements for binding sites on soil particles and in the plants' root system, thereby changing plant trace element concentrations.

We investigated the effect of various levels of DE application on the growth, transpiration, and elemental concentrations of *S. kinuyanagi* (Clone No. PN 386), with a view to its use for the land treatment of DE combined with stock fodder production. Potentially, *S. kinuyanagi*, already proven to mitigate nitrate leaching when irrigated with dairy effluent, could provide a nutritious supplementary feed source that is rich in essential trace elements.

2. Materials and methods

We conducted a lysimeter experiment from September 2004 to February 2005 in a shade house at Plant and Food Research, Palmerston North, New Zealand (40°22′41.94′′S, 175°36′51.01″E, elevation 34 m). A meteorological station installed in the greenhouse recorded temperature, solar radiation, and relative humidity. Table 1 shows the average daily temperatures and potential evapotranspiration, which was calculated using the Penman–Monteith equation. In September, we set up eighteen 0.122 m^3 lysmeters. Each lysimeter was 1 m high and had diameters of 76 cm at the top and 65 cm at the base. The surface area of the soil was 4536 cm^2. Perforated drainage collection tubes (internal diameter 1.2 cm) were installed at the bottom of each lysimeter. The drainage was collected in 0.01 m^3 polythene jerry cans located in a trench below the level of the bottom of the lysimeters. The drainage collection tubes were covered with river gravel with an average particle diameter of 5 mm to a depth of 50 mm. We filled each lysimeter with 900 mm of loamy sand, repacked to a bulk density of 1500 kg m^{-3}. Table 2 gives the chemical properties of the soil. The sand, silt, and clay fractions were 0.84, 0.10, and 0.06 g g^{-1} respectively. The lysimeters were irrigated to field capacity, corresponding to a water content of 46%, and left for two weeks. DE was applied weakly on the surface of the lysimeters.

On the 1st of October (Day Of Experiment, DOE = 1), 12 of the lysimeters were planted with one 1 m unrooted willow rod each, inserted to a depth of 200 mm The poles had an average diameter of 32 mm and an average fresh weight of 540 g. Six of the lysimeters remained unplanted. Table 3 lists the treatments and the amounts of water, DE, and N that the lysimeters received. There were two control treatments (np0, p0), which received only water and four DE treatments (np0.5, p0.25, p0.5 and p1), with mixtures of water and DE. There were three replicates of each treatment distributed in a block design. Fig. 1 shows the experimental set up.

Table 1 – Average daily minimum and maximum temperatures (°C) and average daily potential evapotranspiration (mm) throughout the experiment.

	Minimum temp (°C)	Maximum temp (°C)	Potential evapotranspiration (mm)
September 04	7.4	16.8	2.3
October 04	9.8	19.2	2.5
November 04	11.9	23.6	4.4
December 04	11.5	22.2	3.6
January 05	14.6	26.3	4.5
February 05	20.3	31.7	6.7

Table 2 – Characteristics of the dairy effluent and soil used in the experiment. Concentrations are in g m^{-3} (dairy effluent) and mg kg^{-1} (soil). n.d. = not determined.

	Effluent (g m^{-3})	Soil (mg kg^{-1})
pH	7.8	5.7
Organic carbon	185	9000
Total N	110	475
NH_4–N	95	n.d.
NO_3–N	15	n.d.
P	24	287
S	2	41
K	168	10784
Ca	23	6332
Mg	14	2260
Na	8	3436
Fe	0.62	21729
Zn	0.11	40
Mn	0.68	332
B	<0.1	2.3
Co	n.d.	8.3
Mo	n.d.	1.8
Cl	75	71
Cu	<0.1	10.2