RESPONSE OF SHORT ROTATION FORESTRY TO DAIRY FARM-POND EFFLUENT IRRIGATION

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ABSTRACT

A growing concern to protect the environment has prompted Regional Councils in New Zealand to monitor compliance under the Resource Management Act (1991) covering the discharge of wastewater into waterways. To meet the desired standards, application of wastewater onto high dry matter producing short vegetation forests offers opportunity for the beneficial use of nutrients while renovating the wastewater.

A field trial was established near Palmerston North to determine the response of nine Salix clones and one Eucalyptus short rotation forest (SRF) species to dairy farm effluent irrigation and to determine their water and nutrient uptake potential. A micro sprinkler irrigation system was designed to operate at 100 kPa and supply each plot of 16 trees with either 7.5 mm, 15 mm, or 30 mm of dairy farm effluent every two weeks. Twenty-four applications were made covering two growing seasons with a break over winter. A control treatment of 7.5 mm of water + 187.5 kg N ha^{-1} $year^{-1}$ was included, being equivalent to the nitrogen addition from the lowest effluent application rate. The three SRF species, *Salix matsudana x alba* (NZ 1295), *Salix kinuyanagi* (PN 386) and *Eucalyptus nitens* were selected for more detailed analysis than the other seven Salix clones. This included the measurement of evapotranspiration rates and a pot trial to determine the tolerance level of seedlings to higher levels of effluent application. Application of up to 90 mm of effluent per fortnight increased the biomass production and nutrient accumulation of potted PN 386 and *E. nitens*, whereas the NZ 1295 produced optimum biomass and accumulation of nutrients at 60 mm of effluent application per fortnight.

At the end of the first growing season, the above ground biomass of the ten tree species in the field trial was assessed using a non-destructive method followed by a destructive harvest at the end of the second growing season. Dry matter production in these short rotation forest crops varied with species and clones and with the amount of dairy farm-

pond effluent applied. *Salix* NZ 1296, PN 386 and NZ 1295 irrigated with the highest application rate of 30 mm of effluent per fortnight produced the highest biomass yields of 37.91, 37.87 and 37.58 ODt ha^{-1} $year^{-1}$ respectively. NZ 1296 irrigated with 30 mm of effluent per fortnight accumulated 196 kg N ha^{-1} $year^{-1}$, 37.6 kg P ha^{-1} $year^{-1}$, and 103.6 kg Mg ha^{-1} $year^{-1}$ in its above ground biomass. *E. nitens* irrigated with 15 mm of effluent per fortnight produced a comparable above ground oven dry biomass yield of 36.33 ODt ha^{-1} $year^{-1}$ and accumulated the highest amount of potassium and calcium in its above ground biomass giving 145.4 and 148.1 kg ha^{-1} $year^{-1}$, respectively.

Transpiration monitoring during the second growing season using a heat pulse technique showed that under the highest application rate (30 mm per fortnight) on a cloud-free day, 15 month old NZ 1295 trees each transpired the highest cumulative amount of 6.38 mm day^{-1} compared to 2.71 mm day^{-1} for trees irrigated at the lowest rate (7.5 mm per fortnight).

Results of this study overall suggest that increasing the rate of effluent irrigation will increase the soil pH, nitrates and exchangeable potassium, calcium and magnesium concentrations throughout the soil profile. Total nitrogen and total phosphorus levels decreased throughout the soil profile after the second growing season. The cation exchange capacity of the soil decreased with increased rate of effluent after the second growing season.

The soil-SRF treatment system renovated the nutrients in the effluent. The soil-*E. nitens* treatment system renovated the highest percentage of total nitrogen (17.2 t ha^{-1} m^{-1} depth) equivalent to 96.45% of total nitrogen supplied by both the soil and the 30 mm of effluent applied per fortnight. The soil-PN 386 treatment system renovated the highest percentage of total phosphorus (6.4 t ha^{-1} m^{-1} depth) equivalent to 92.72% of the total phosphorus available in the soil and supplied by the 7.5 mm of effluent treatment. The soil-NZ 1295 treatment system renovated the highest percentage of potassium (99.5%),

calcium (98.74%) and magnesium (95.63%) supplied by both the soil and the 30 mm of effluent treatment.

The capacity of the three SRF species to renovate total nitrogen, phosphorus and potassium from the effluent decreased with increasing rates of application. PN 386 irrigated at 7.5 mm of effluent renovated the highest percentage of 99.45% of total nitrogen (114.25 kg ha^{-1} over two growing seasons) and 79.18% of total phosphorus (35.60 kg ha^{-1} over two growing seasons). The amounts of calcium and magnesium renovated by the SRF species were more than the amount supplied by even the highest rate of effluent (30 mm per fortnight).

Salix PN 386, NZ 1295 and *E. nitens* are recommended SRF species to grow in a land treatment scheme for dairy farm pond-effluent when applied at a rate of 30 mm per fortnight over the growing period on to a silt loam soil. Pot trials showed higher volumes of effluent renovation on to PN 386 and *E. nitens* may be applicable when applied up to 90 mm of effluent per fortnight but further evaluation is needed before this can be recommended.

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CHAPTER 1

INTRODUCTION

Many dairy farms treat the dairy shed washings in anaerobic/aerobic ponds before discharge of the treated effluent to pasture or waterways. This system can still have a large impact on receiving waterways as the effluent contains relatively high levels of nutrients and pollutants which threaten the environment once discharged or allowed to percolate into the ground water (Mason, 1994). Potassium and nitrogen contents of dairy farm-pond effluent is particularly higher compared with sewage effluent.

A growing concern to protect the environment has prompted regional councils in New Zealand to monitor compliance under the Resource Management Act (1991) covering the discharge of wastewater into waterways. To meet the desired standards, application of wastewater onto high dry matter producing short rotation forests (SRF) offers opportunity for the beneficial use of nutrients while renovating the wastewater (Barton et. al, 1989).

Irrigation of land with dairy farm-pond effluent is one of the alternatives to discharge and a soil-SRF treatment system has the potential to effectively treat the effluent when applied at a regulated hydraulic loading rate. The soil particles can filter suspended solids and can fix dissolved components in the effluent by adsorption, ion exchange or precipitation. Micro-organisms in the soil can transform and stabilise the nutrients from the wastewater. The growth of SRF species on treatment site can enhance absorption and utilise nutrients from the wastewater for growth and production. The SRF root system can also help improve the infiltration capacity of the soil.

SRF crops like willows and eucalyptus are fast growing species and are known to produce high dry matter. Sims et. al (1992) recommended coppice willows to be ideal attachment for land treatment of wastewaters due to its fibrous root system that has the ability to utilise large quantity of water and nutrients. Barton (1989) emphasised the potential use of coppice eucalyptus for wastewater treatment being able to accumulate high amounts of nitrogen. These SRF species has also the potential to provide non-polluting sources of renewable energy while renovating waste waters.

Aside from preventing the possible risk of ground water contamination and eutrophication of waterways, it is desirable to recycle nutrients from wastewater wherever feasible to support sustainable crop production. Hence, it is the purpose of this study to investigate the performance of short rotation forest species, *salix* and *eucalyptus* as part of a land treatment scheme for dairy farm-pond effluent.

Specifically, this study aimed to:

- identify suitable SRF species for dairy farm-pond effluent irrigation;
- quantify the level of dairy farm-pond effluent irrigation suitable for the production of SRF species;
- determine the effect of dairy farm-pond effluent to the physical and chemical properties of soils;
- quantify the amount of waste nutrients from dairy farm-pond effluent renovated by the SRF species;
- quantify the amount of nutrients renovated by the soil-SRF system that were supplied by the soil and the effluent and;
- determine the evapotranspiration of SRF species when irrigated with varying rates of dairy farm-pond effluent.

An overview of previous work is given in chapter two of the thesis.

The responses of ten species to different rates of dairy farm-pond effluent irrigation and water + nitrogen in terms of biomass production and nutrient accumulation were evaluated (chapter 3). The three most suitable species or clones of SRF trees for treating dairy farm-pond effluent irrigation were identified and the level of irrigation that produced optimal biomass production and nutrient uptake and accumulation into the biomass was determined.

The effects of applying different rates of dairy farm-pond effluent to the physical and chemical properties of the soil were discussed in chapter 4. Samples were analysed before treatment began and after harvesting the trees at two years old.

The portion of waste nutrients in the dairy farm-pond effluent applied at the various application rates that was renovated by the SRF trees and filtered by the soil matrix over the two growing periods was quantified (chapter 5).

The effect of dairy farm-pond effluent irrigation on the evapo-transpiration of the three selected species was monitored during a short period of the growing season and is reported in chapter 6.

Finally, the responses of seedling of the three selected SRF species to particularly high rates of dairy farm-pond effluent irrigation were determined in a pot trial described in chapter 7. The maximum irrigation level of dairy farm-pond effluent irrigation that was tolerated by each of the three SRF species in terms of maximum growth, biomass production and nutrient accumulation was determined.

The results of these studies were brought together in concluding section (chapter 8) and practical recommendations made along with suggestions for further studies.