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Use of turnips to reduce potassium accumulation on areas receiving Farm Dairy Effluent

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Abstract

Land treatment of farm dairy effluent (FDE) on small areas of intensive of dairy farms has enriched soils with nutrients particularly K. Solving the problem solely by increasing the area allocated for land treatment requires large investment in pump, pipes and irrigator infrastructure. A less costly strategy, of sowing and grazing a summer turnip on the land treatment area in order to redistribute K to the pasture area is evaluated in this thesis. A survey (February 2006) showed that in the Manawatu region turnip crop yields (8 to 17t DM.ha^{-1}) provided profitable feed for dairy cows, were a suitable re-grassing strategy and if harvested, removed 350 to 700 kg K ha^{-1} from the soil. In the summer of 2005/06, a turnip (*Brassica rapa* cv. Barkant) trial was established after permanent pasture on a Pallic soil (pH 6.5, Olsen P 35.2 ug. g^{-1}, exchangeable K^+ 0.7, Ca^{2+} 6.3, Mg^{2+} 1.4 me/ 100 g soil). The following treatments pre-plant fertiliser only (38 kg N ha^{-1}, 25 kg P ha^{-1} and 25 kg K ha^{-1}), pre-plant fertiliser plus side-dressed urea at 40 DAS (46 kg N ha^{-1}) and pre-plant fertiliser plus 5 x 10 mm FDE applications (57kgha^{-1}) all produced similar final dry matter yields (8 t DM ha^{-1}) at 100 days after sowing (DAS). Leaf was the largest component of dry matter and had higher K concentrations (4.6 and 6.8% K in the control and FDE treatments respectively) than bulb (3 and 4 %K in the control and FDE treatments respectively). The ratio of leaf to bulb dry matter however varied for each different treatment. Side-dressed urea and FDE treatments produced the largest leaf biomass and reached maximum yields earlier by 75 DAS and 64 DAS, respectively and generated more K removal at harvest (339, 428 & 537 kg K ha^{-1} at 75 DAS and 316, 372 & 490 kg K ha^{-1} at 100 DAS for pre-plant only, urea & FDE treatments, respectively).

The lack of yield response to N partially resulted from crop uptake of between 107 and 114 kg N ha^{-1} from mineralisable soil N. The dynamic N crop model N-able predicted that extra side-dressed N would not increase turnip yield but in the absence of pre-plant N (38 kg N ha^{-1}) the turnips would yield 7.4 t DM ha^{-1} at 100 DAS. The use of the N-

able model demonstrated a need for a decision support model to assist farmers in choosing appropriate N fertiliser application rates.

A simple model was created to simulate how the grazing cow can transfer K from turnip paddocks (part of a FDE treatment block) to other parts of the farm. The model simulation of 490 cows on a mixed diet of 4kg DM turnips and 12 kg DM pasture predicted that the grazing of turnips (8t DM ha^{-1} crop) would result in the net transfer of significant quantities (>170 kg K ha^{-1}) of K from land growing turnips to other parts of the farm. To cause net transfer to occur the allocated turnip dry matter must be grazed in the shortest time possible and the cows returned to pasture after short milking times.

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Introduction

1.1 Intensification of Dairying and the accumulation of potassium under land treatment of FDE

The intensification of dairy farming in New Zealand over the last 10 years has resulted in an increase in the average stocking rate of 10% i.e. from 2.48 cows ha^{-1} to 2.75 cows ha^{-1} (LIC, 2003/04). By 1999/00, the top 25% of farmers (herd size > 300 cows) had also increased the amount of supplementary feed purchased so that the average amount of supplement brought onto the farm was 670 kg DM cow^{-1} or 2069 kg DM ha^{-1} (Leslie, 2002). This increased use of supplementary feed and fertiliser has led to greater inputs of nutrients into dairy farm systems.

Increased stocking rate leads to the generation of greater volumes of farm dairy effluent (FDE). By 2003/04, approximately 63 million m^{-3} $year^{-1}$ of FDE was being generated (LIC, 2003). Mismanaged irrigation of FDE to land can create a number of problems (Bolan et al., 2004; Houlbrooke et al., 2004) including:

- High application rates generating runoff and drainage of partially treated FDE, which pollute surface and ground waters.
- Excessive FDE loads leading to N and K enrichment of topsoils increasing the risk to animal health, plant quality and soil quality.
- Nutrient enrichment of winter drainage water
- Wet easily, pugged soils
- Localized areas that receive higher rates of effluent which exceed the soil's infiltration rate. Therefore, patches of saturated soil, preferential flow of FDE through the soil profile, soil structure damage, poor plant growth, etc.

Therefore, nutrient enrichment on land receiving FDE becomes a potential risk. The nutrient concentration in FDE varies widely from farm to farm (Longhurst *et al.*, 2000) but typically the N, P and K concentrations range from 181 to 400 mg N l^{-1}, 40 to 80 mg P l^{-1} and 164 to 705 mg K l^{-1}, respectively (Longhurst *et al.*, 2000). Whilst high and poorly timed application rates of N and P in FDE can cause undesirable N and P enrichment of drainage (Houlbrooke *et al.*, 2004) and surface waters (Monaghan et al. 2004), the high concentration of K in FDE can cause excessive K accumulation in soils of areas that receive FDE. Paddocks that are irrigated with FDE at the appropriate N loading rate for regional council consent (150-200 kg N ha^{-1}) accumulate and presumably leach large amounts of K (Bolan *et al.*, 2004). This results in pastures on effluent paddocks with high K contents and reduced Mg and Ca contents (Bolan *et al.*, 2004). For example, the nutrient budgeting tool 'Overseer® Nutrient Budgets 2' predicted that K was added as effluent at rates of 354 and 154 kg ha^{-1} y^{-1} to the effluent areas of two dairy farms in North Otago (3.7 cows ha^{-1}, Lynch, 2006) and Waikato (4.7 cows ha^{-1}, Payze, 2006), respectively. The variation in concentration depended partially on the area of the effluent blocks on each farm. Cows left for a long time to graze these paddocks may suffer from metabolic disorders (Hypocalcaemia and Hypomagnesaemia).

Problems caused by application of FDE to wet soils are being addressed by FDE storage and deferred irrigation. This system is advocated by most regional councils (Houlbrooke et al., 2004). The management of deferred irrigation has been improved by the use of irrigators, such as the k-line system, that are able to apply small depths (less than 5 mm) of FDE to soils (Houlbrooke *et al.*, 2006). While such modification will minimise the risk of N and P loss to the aquatic environment, additional strategies are required to reduce the K loading and accumulation in soils.

1.2 Solution to this problem: Strategies to reduce the accumulation of K on areas receiving FDE

1.2.1 Extension of effluent area

The current criterion for applying FDE to land is based on Regional Council regulations for appropriate N loading of which 200 kg N ha^{-1} y^{-1} is the limit (Heatley, 1996). The land area recommended for FDE treatment is currently 4 ha per 100 cows (Heatley, 1996), but a new proposal suggests that the area should be based on the proportion of dung and urine that is collected from the herd. This can be estimated from the average time a cow spends off the paddock in the collecting yards and milking shed and/or feed pad (Hedley *et al.*, 2004). To prevent K accumulation in soil, the annual K loading rate should not exceed the annual K maintenance requirement of grazed pasture. This requires irrigation of FDE to a larger proportion of the farm (30-40%) than is currently used to meet the N requirements (10 -15 %). A number of case studies where areas allocated for land-treatment of FDE are described below.

Hedley *et al.*, (2004) described a farm in the Bay of Plenty with 580 cows and an original effluent area of only 19 ha. It was proposed to increase the FDE area to 43 ha (30% of the whole farm) to improve management of FDE. Nutrient application rates to the expanded area were reduced by up to 50%. Of course enlarging the effluent area requires increased expenditure on an upgraded irrigation system. In this case study, the predicted cost of installing additional irrigation on the 43 ha plus annual running costs was around $8917 per year, which allowed a saving of $9400 per year in fertiliser costs (Hedley et al., 2004).

Two dairy farm case studies (in North Otago and Waikato) used the Overseer® nutrient budgeting model to assess the impact of nutrient management recommendations on efficiency of nutrient use in, and nutrient loss from, the effluent blocks. The two farms,

where the soil nutrients levels were already equal to or greater than optimum agronomic value for pasture, increased the area of effluent application up to the total farm area. The North Otago dairy farm reduced the application rates of nutrients by about 87%, by use of the new irrigation system. However, the predicted investment in the new irrigation system was very large (Lynch, 2006). On the other farm (Waikato) extending the application area to be equal to the whole farm area decreased the nutrient content applied to the effluent paddocks by about 53% (Payze, 2006). The difference in the sizes of the nutrient reductions in the two farms were due to the different stocking rate (3.7 and 4.7 cows ha^{-1}) and the size of the previous effluent blocks (25 and 85 ha).

1.2.2 Crop nutrient removal

Hedley *et al.*, (2002) proposed that the harvesting of silage, or hay, to remove K from the FDE area will avoid the need for excessively large land-treatment areas. For instance, Overseer® was used to simulate the ability of maize silage (spring planting) followed by barley/triticale (autumn planting) to remove nutrients for FDE paddocks on a Bay of Plenty farm (Hedley *et al.*, 2004). If these two crops yielded 27 and 5 ton DM ha^{-1}, respectively, the combined nutrient removal was predicted to be 414 kg N ha^{-1}, 61 kg P ha^{-1} and 288 kg K ha^{-1}. Annual grass silage harvesting in spring and summer, which yields a total dry matter production of 6 t DM ha^{-1}, will remove less nutrient at 187 kg N ha^{-1}, 27 kg P ha^{-1} and 133 kg K ha^{-1} (Hedley *et al.*, 2004). Another problem in using grass silage as a nutrient removal strategy is that in many areas of New Zealand, wet soils in winter and spring delay the commencement of 'safe' effluent irrigation to late spring and summer. The window of opportunity to harvest hay and silage is reduced and crop sizes of 3.5 to 5 t DM ha^{-1} are expected. Therefore, K extraction and removal can remain low relative to inputs in the FDE.

Summer crops such as maize and turnips offer the opportunity to produce larger amounts of dry matter with higher metabolisable energy content (Table 1.1) than conserved pasture (Table 1.2) and therefore are attractive as fodder crops for summer dry areas. In addition, for the same growing period, the higher yields of maize silage and turnips remove more nutrients than pasture silage (Table 1.2). Turnips, in particular,

have higher tissue K concentrations (Table 1.1) and remove markedly more K when harvested (grazed). For example, at a yield of 10 t DM ha^{-1}, turnips extract 10% less N and P but 40% more K and S than a crop of maize yielding 18 t DM ha^{-1}. If the turnips and maize had similar yields (18 t DM/ha) then the turnips would remove 60% more N and P and 150% more K and S (Table 1.2)

Table 1.1 Nutrient content of different crops that could be grown to remove excess K from the soil

				Nutrients (%)					
	DM (%)	MJ ME/kg DM	CP (%)	N	P	K	S	Ca	Mg
Pasture Silage/Baleage	35	9.5	16.0	3.5	0.29	2.2	0.22	0.70	0.18
Maize silage	33	10.3	8.0	1.3	0.23	1.2	0.13	0.25	0.18
Turnip crop	10	12.5	13.0	2.1	0.37	3.0	0.33	1.75	0.23

Source: Holmes *et al.*, 2002. Milk production from pasture. Principle and practices.

Table 1.2 The effect of crop type and yield on the removal of K from the soil

		Nutrients (kg ha^{-1})			
	Yield t ha^{-1}	N	P	K	S
Pasture Silage/Baleage	2 - 4	70 - 140	6 - 12	44 - 88	4 - 8
Maize silage	18	234	41.4	216	23.4
Turnip crop	10	210	37	300	33
Turnip crop	18	378	66.6	540	59

[1] Source: The silage and baleage yields are from the Dexcel website (2006) www.dexcel.co.nz; the maize and turnip yields are from Holmes C. (Personal comm.).

Factors such as the timing of growth, available finance, and plant nutritive qualities would also affect farmers' decisions as to which crop to grow. At 0.08 – 0.12 $/kg DM, turnips have the lowest cost per kg DM produced. Therefore, turnips could be a "best option" for this new strategy of nutrient harvest by a crop because, unlike maize, they require no specialized machinery nor added contractors costs to plant and harvest (feed to cows). However, many dairy farmers prefer to buy maize silage rather than cultivate (Holmes pers com, 2005).

Table 1.3 Approximate cost per kg DM produced and the harvesting time of crops

	Cost $/kg DM	Harvest time (weeks)
Pasture Silage/Baleage	0.40 - 0.45	4 - 8
Maize silage	0.15 - 0.21	24 - 28
Turnip crop	0.08 - 0.12	10 - 12

Source: www.dexcel.co.nz

Forage crops such as turnips are grown for the following reasons:

- Provide a large quantity of high quality feed during summer months to increase milk production at this time (decreasing the fall in milk production that normally occurs at this time from 14 % to 7% month (McGrath *et al.*, 1998; Daniels, 1995).

- A pasture renewal strategy to introduce new productive pasture species free of endophytes, and clean the soil of pests, weeds and diseases;

- Improve soil structure and surface micro-topography by levelling or draining during the cultivation phase.

- Less stressful time for the farmer.

In addition, they could be sown on effluent areas and on/off grazed to aid the redistribution of effluent borne K around the other grazed areas of the farm.

1.3 Research Objectives and Thesis Structure

The objective of the research presented in this thesis is to provide more information on the role that a summer turnip crop could play in redistribution of K from soils that have been enriched with K by FDE application. This study involves a survey of turnip crops grown in the Palmerston North region, a field trial evaluating the K removal potential of Barkant turnips grown under FDE irrigation and two exercises in modelling the crop N requirement and K transfer by cows grazing a mixed diet of turnips and pasture.

This thesis has the following objectives:

- Review how intensive dairy farming increases the concentration of nutrients in effluent paddocks.
- Survey local turnip crops for yield and nutrient content at harvest.
- Measure the ability of turnips (*Brassica rapa* cv. Barkant) to take-up K under normal fertilization and FDE irrigation
- Use of N-able model to assess the amount of N fertiliser that is required to achieve high turnip yield.
- Build a simple model to evaluate the K transfer potential of different grazing strategies for cows on a mixed diet of turnips and pasture.

1.4 References

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