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Short communication

Treatment of pasture topsoil with alum to decrease phosphorus losses in subsurface drainage

R.W. McDowell [a,b,*]

[a] AgResearch, Invermay Agricultural Centre, Private Bag 50034, Mosgiel, New Zealand
[b] Agriculture and Life Science, Lincoln University, Lincoln 7467, New Zealand

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ABSTRACT

Phosphorus loss from land can impair surface water quality. Losses *via* subsurface flow can be substantial, but most strategies to mitigate P losses focus on surface runoff. Aluminium sulphate (alum) was applied at 25 and 50 kg Al ha^{-1} to a flat, podzol soil under pasture regularly grazed by dairy cattle. Over a year, losses of filtered (<0.45 μm) reactive P (FRP) and total filtered P (TFP) intercepted at 35-cm depth by Teflon suction cups were *c.* 0.6 and 1.0 kg P ha^{-1}, respectively for the control treatment. The 50 kg Al ha^{-1} treatment decreased FRP and TFP by 26 and 27%, respectively: no significant difference to the control was noted for alum applied at 25 kg Al ha^{-1}. The cost-effectiveness was estimated at 190–952 USD kg^{-1} P mitigated. While more cost-effective strategies should be practised first, surface applying alum may provide an option where sub-surface P losses must be lowered further especially if applied to a small area of high P loss.

1. Introduction

The loss of P from land can impair surface water quality *via* eutrophication (Carpenter et al., 1998). In a review of New Zealand land uses, McDowell and Wilcock (2008) found that P losses were enriched from dairy-farmed land. Under certain soil physical (*e.g.* low slope) or chemical (*e.g.* poor P sorption capacity) conditions, subsurface flow can be a more important mechanism of P loss than surface runoff. In the New Zealand soil classification (Hewitt, 1998), many podzol soils are prone to subsurface P losses (*viz.* leaching) due to a combination of high hydraulic conductivity, poor anion storage capacity (ASC: an indicator of P sorption capacity; McDowell and Condron, 2004), and macropore flow especially if intercepted by artificial drainage (Monaghan and Smith, 2004).

Strategies to mitigate P loss from dairy systems have focused on minimising losses by surface runoff. However, there are far fewer strategies to mitigate P losses *via* subsurface flow. In a review of potential technologies to remove P in drainage water, Buda et al. (2012) highlighted several structures that filter-out P from drainage water such as flue gas desulfurization gypsum ditch filters (Bryant et al., 2012), the use of iron oxides in and around tile drains (McDowell et al., 2008; Chardon et al., 2012), and steel slag filter beds to remove P from drainage water at catchment outlets (Penn et al., 2012). However, McDowell and Nash (2012) also noted that as scale and complexity of flow-paths increased the cost-effectiveness of strategies to mitigate P loss decreased. Strategies that aim to decrease P loss most cost-effectively focus on decreasing the availability of P at source; for example, by decreasing soil Olsen P concentration (McDowell and Nash, 2012).

In many soils, especially those used for intensive pastoral grazing, maintaining soil Olsen P as low as agronomically possible may still lead to substantial P loss *via* subsurface flow due to poor P sorption capacity and continual inputs from excretal returns (McDowell and Nash, 2012). One amendment, aluminium sulphate (alum) has been used to decrease the potential for P loss in surface runoff (*e.g.* McDowell and Norris, 2014). Alum was therefore tested to determine if it could also be used to cost-effectively decrease P loss in subsurface flow from a grazed pasture.

2. Methods and materials

2.1. Preliminary leaching trial

A preliminary leaching trial was conducted using a Tisbury silt loam soil (Typic Perch-gley podzol in the New Zealand soil classification – equivalent to an Aquod in US Taxonomy; Hewitt, 1998) from pasture-based grazed dairy farm >10 years old. Soil was sampled of the 0–7.5-cm depth, broken up by hand to remove plant roots and passed through a 2-mm sieve. A sub-sample was dried and analysed for ASC (Saunders, 1965) as a measure of the soil's

* Corresponding author. Tel.: +64 34899262; fax: +64 34893739.
E-mail address: richard.mcdowell@agresearch.co.nz (R.W. McDowell).

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Table 1
Soil test values with depth at the field site. The least significant difference at the $P < 0.05$ level of significance (LSD_{05}) is given for the comparison of means for each depth.

Depth (cm)	Soil test			
	Olsen P ($mg\,L^{-1}$ soil)	WSP ($mg\,L^{-1}$ extract)	ASC (%)	pH
0–7.5	51	0.18	47	5.7
7.5–15	46	0.15	61	5.0
15–30	31	0.10	60	4.9
30–45	21	0.09	60	4.7
45–60	11	0.05	82	4.5
60–100	4	0.02	91	4.3
LSD_{05}	5	0.03	12	0.3

P-sorbing Al and Fe oxide concentration, Olsen P concentration (Olsen et al., 1954) and water extractable P (WEP; McDowell and Condron, 2004). Eighty grams of field moist soil was placed inside 100-cm^3 syringes (3-cm diameter) with some glass wool at the end to prevent soil loss. Alum was applied at rates of 0, 32, 64, 160, 320, 640, 1600 $kg\,ha^{-1}$, equivalent to 0, 5, 10, 25, 50, 100, 250 $kg\,Al\,ha^{-1}$ to the surface of 6 replicates each – yielding 42 syringes in total. Soils were leached with 40-mm of deionised over 8 h, 2, 15, 22, 29, 37 and 44 days after alum was applied. Leachate samples passed through a 0.45 μm filter and analysed for filtered reactive P (FRP) and pH (1:2 soil to water ratio).

2.2. Field trial

Alum was applied in October 2012 at 0, 25 and 50 $kg\,Al\,ha^{-1}$ to the same paddock used to collect the Tisbury silt loam (Table 1). The site had a slope of <1% and artificial drains installed at 70–80-cm depth to facilitate drainage to adjacent 1-m deep open channel drains. The paddock received regular annual fertiliser of a single application of 32 $kg\,P\,ha^{-1}$, 45 $kg\,K\,ha^{-1}$ and 100 $kg\,Ca\,ha^{-1}$ (as lime) as part of the wider dairy farm's milking platform in December. Split applications of 30 $kg\,N\,ha^{-1}$ as urea were applied in September, November, January and March. Paddocks on the milking platform were rotationally grazed every 24–28 days

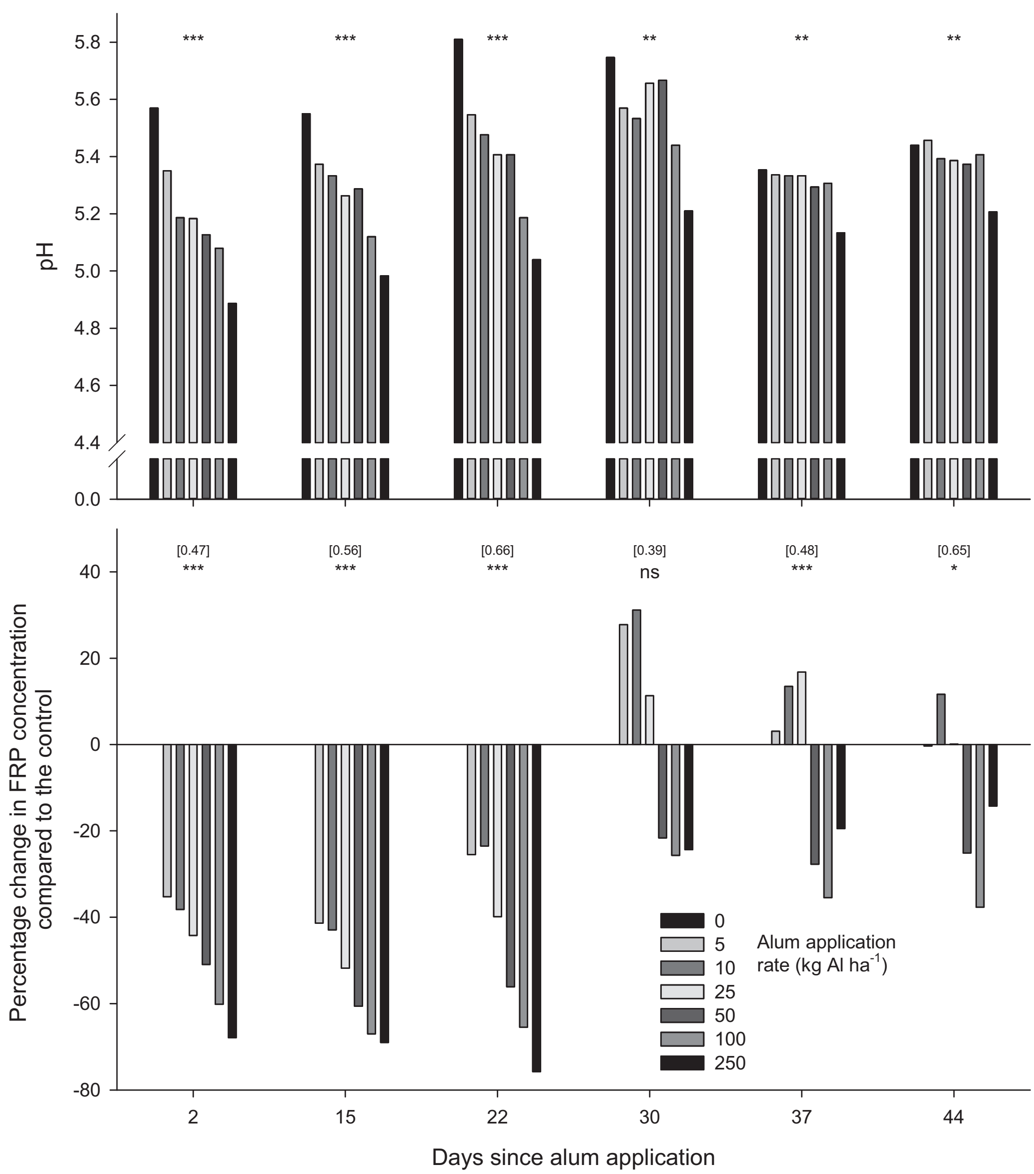

Fig. 1. Mean leachate pH and percentage change compared to the control for filtered reactive P (FRP) concentration with time after different rates of aluminium sulphate was applied. Values in parentheses are the mean concentration of FRP in leachate for the control. An asterisk indicates a significant difference in mean FRP concentrations between rates for each event (** and *** indicate significance at the $P < 0.01$ and < 0.001 level, respectively).