Establishment of a split grass-clover system to improve water quality and profitability

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Abstract
Surface water quality can be impaired by phosphorus (P) loss from land. The lower Olsen P requirement of ryegrass compared with clover can, when growing them separately, allow for more targeted application of nutrients and better profitability than is possible for a mixture. Creating areas of low P (e.g. near streams) can improve water quality. Modelled results of a split white clover-ryegrass system for a dairy farmed paddock in Southland, indicated that it would improve profitability by $46/ha, compared with a mixed pasture receiving 150 kg N/ha. A field trial tested the best method of converting to the split grass-clover system to decrease P loss. Compared with direct-drill or restricting P applications, cultivation decreased the concentration of P in the topsoil and distributed this P more uniformly throughout the plough layer. This suggests that in areas such as near streams where runoff is likely to move nutrients such as P to waterways, ryegrass established by cultivation to 15 cm, and the application of P to maintain an Olsen P concentration no greater than agronomically optimum, is a quick method of maintaining pasture production while minimising the loss of P to surface waters.
Keywords: eutrophication, Olsen P, superphosphate, runoff, ryegrass, white clover

Introduction
Phosphorus (P) is a common nutrient causing freshwater eutrophication worldwide (Carpenter *et al.* 1998). This is also true of New Zealand streams and rivers, where in a recent study, up to 87% (612) of stream and river sites were negatively affected by too much P (McDowell *et al.* 2009). Increased intensification, largely in the dairy industry, and reflected in enriched Olsen P concentrations, has been linked to an increase in P losses and a decline in surface water quality (Hamill & McBride 2003). Best management practices (BMPs) are sought to mitigate P losses from land to water.

One common recommendation to decrease P loss is to maintain soil test P (Olsen P) as low as "agronomically" possible. In grass-legume pastures, production is driven by the response of legumes, more than grasses, with increasing soil Olsen P concentrations (Mouat & Nex 1983; Gillingham *et al.* 2008). Hence, in mixed pastures there may be little scope to decrease Olsen P to a low concentration to decrease the potential for P loss, without restricting the growth of legumes such as white clover.

Recently, a split grass-clover system, where part of the paddock is sown in a monoculture of ryegrass and part in a monoculture of white clover has been shown to improve the milksolids production in dairy cattle (Cosgrove *et al.* 2006) and liveweight gain in lambs (Cosgrove *et al.* 2003), compared with conventional mixed ryegrass-white clover pasture. This forage management system is most appropriate when implemented on a small proportion of the farm area for feeding to a responsive class of stock (Cosgrove *et al.* 2006). Hence, if this system and a ryegrass monoculture, with a lower requirement for soil Olsen P concentration compared with white clover, could be located in the small parts of the catchment known to produce runoff, this should decrease P loss. However, converting, for example, a dairy farm with high Olsen P concentration to a split grass-clover system may not necessarily benefit surface water quality if topsoil is still enriched with P and runoff is likely to occur. Cultivation has been shown to mix the topsoil and redistribute nutrients such as P more uniformly through the topsoil (Sharpley 2003). This paper aimed to: 1) model the potential profitability of a split grass-clover system for a Southland dairy farm over 10 years, and 2) determine the quickest way to decrease potential P loss with the split grass-clover system on a high Olsen P soil under different rates of P application and two methods of pasture establishment (cultivation versus direct-drill).

Materials and Methods
Site and trial design
The trial was conducted at the Woodlands research farm near Invercargill. The soil is a well-drained Firm Brown Waikiwi silt loam (Bruce 1977) that receives 1000-1300 mm of rainfall annually. The 0.5 ha paddock chosen for the trial was flat (<1% slope) and had been grazed by

sheep for >20 years. The soil Olsen P concentration since 2005 ranged from 35 to 40 mg/kg.

After spraying the paddock with glyphosate (540 strength, applied at 3 L/ha) on 1 September and 21 October 2008, and cultivating half of the trial area on 23 October by ploughing, rolling, rotary hoeing to a depth of 7 cm and levelling, 108 plots, each 2 x 6 m with 1 m gap between them, were sown on 3 November the 2008. Six replicates of the following treatments were created, and statistically analysed, in a randomised block design:

- Pasture treatments: three pasture treatments consisted of white clover (*Trifolium repens*, cv. 'Demand') or ryegrass (*Lolium perenne*, cv. 'Supreme' AR1 endophyte) each sown as monocultures and a mixed ryegrass-white clover sward. White clover was sown at a rate 8 kg/ha and ryegrass (diploid) was sown at 24 kg/ha. The mixed sward was sown at a rate of 20 kg ryegrass/ha and 4 kg clover/ha.
- Method of establishment: two treatments consisted of either cultivation (twice) to 15 cm depth followed by drilling (termed cultivation) of ryegrass seed using an Aitchison drill or just direct-drilling of ryegrass seed using the same drill (termed direct-drill). Clover was surface-sown by hand onto both direct-drill and cultivated treatments.
- Rates of P application; Superphosphate (9% P, 11% S) was applied at 10, 35 or 100 kg P/ha, 3 weeks after cultivation (2 weeks after sowing).

To replace nitrogen (N) normally fixed by white clover in a mixed sward, the ryegrass only treatment received five applications of 30 kg N/ha as urea from August to May.

Measurements

Pasture cuts began in January 2009 and took place whenever dry matter (DM) in the majority of plots was estimated to exceed 3000 kg/ha. Nine cuts were made, each to a residual DM of *c*. 1200 kg/ha. After each sample harvest the entire paddock was cut with a tractor mower to *c*. 1200 kg DM/ha and stock were put on to the plots for long enough to eat the cut material but not to graze the uncut residual. This cutting of the entire paddock ensured that the clover monocultures were not over-grazed. Dry matter content was determined gravimetrically on a sub-sample and recorded.

Starting in October 2008, and then monthly, two soil core samples were taken from each plot to 7.5 cm depth. These were air-dried, crushed, passed through a 2 mm sieve and analysed for Olsen P and water extractable P (WSP: used to estimate the potential P loss in surface runoff; McDowell & Condron 2004). Additional soil samples were taken to a depth of 30 cm in August 2008 (before treatments were imposed) and in January 2009 after superphosphate had equilibrated with the soil (at least 60 days; McDowell *et al.* 2003). These cores were then cut into segments representing 0-2, 2-5, 5-7.5, 7.5-10, 10-15, 15-20 and 20-30 cm depths, and analysed for Olsen P and water extractable P as described above.

Modelled farm performance

An analysis of the potential return for a Southland dairy farm was made using the Udder dairy farm simulation model (Hart *et al.* 1998; Larcombe 1999). The modelled farm was 380 ha with a herd size of 1080 cows. It was assumed that conventional cultivation was used to establish the split grass-clover system. Here, white clover comprised 60% of the milking platform and received P at 35 kg P/ha annually to maintain an Olsen P of 32 mg/kg. The remaining 40% that was ryegrass received 150 kg N/ha (split as above) and 10 kg P/ha each year to maintain growth and an Olsen P of 10 mg/kg. As a comparison, the mixed sward received 150 kg N/ha and 35 kg P/ha across the entire area to maintain an Olsen P of 32 mg/kg. Pasture growth rate and metabolisable energy (ME) of ryegrass and white clover were obtained from Cosgrove *et al.* (2003) and long-term data from previous trials at Woodlands (C. Smith pers. comm.).

Results and Discussion

Modelled cost benefit analysis

Pasture growth rate data indicated that pasture digestibility for the Udder model should be increased by 7% assuming that a ryegrass and clover swards had a ME of 11.5 and 12.3, respectively. Udder output was then adjusted by matching the supply and demand of feed to appropriate times of year. This resulted in a gross margin of $1461/ha for the split grass-clover system and $1365/ha for a mixed pasture system, at a payout of $5/kg milksolids. However, to establish the split grass-clover system, paddocks would have to be ploughed, grubbed, tilled, harrowed and drilled with seed. Depending on the contractor, this equalled a cost of $300-550/ha. Splitting the cost over the 10 year life time of the pasture, and accounting for a 10% opportunity cost, equated to an annual cost of about $50/ha. Deducting this annualised cost from the improved gross margin reported above, the overall financial benefit to the farmer of the modelled Southland dairy farm would be $46/ha (excluding the cost of maintaining weed-free monocultures). However, the reader should note that this is an average return over 10 years and that the return in the first few years after establishment of a split-grass clover system may not be as good as a mixed sward.

Table 1 Mean water soluble P (WSP) and Olsen P concentration in topsoil (0-75 mm) and the total yield from sowing in November 2008 to January 2010. The *F*-statistic is given for all comparisons of treatments and interactions between treatments.

Pasture	Method of establishment	P applied (kg P/ha)	WSP (mg/L)	Olsen P (mg/kg)	Yield (kg DM/ ha)
Clover	Direct-drill	10	0.072	42.6	9078
		35	0.081	49.1	8704
		100	0.087	54.1	8939
	Conventional	10	0.039	21.5	9116
		35	0.047	26.9	9217
		100	0.061	40.0	9082
Ryegrass	Direct-drill	10	0.062	39.6	13849
		35	0.071	44.8	14419
		100	0.081	52.2	14623
	Conventional	10	0.039	19.4	13011
		35	0.040	24.8	12787
		100	0.044	28.2	12713
Mixed	Direct-drill	10	0.066	41.3	14388[1]
		35	0.078	46.5	14137
		100	0.084	53.8	14623
	Conventional	10	0.037	19.8	13132
		35	0.037	22.9	13543
		100	0.048	30.0	14084
F-statistic					
Pasture			0.100	0.098	<0.001
Cultivation			<0.001	<0.001	<0.001
P applied			<0.001	<0.001	0.435
Pasture × Cultivation			0.486	0.558	<0.001
Pasture × P applied			0.827	0.869	0.385
Cultivation × P applied			0.394	0.948	0.930
Pasture × Cultivation × P applied			0.389	0.637	0.270

[1] Dissection of pasture in the mixed sward plots on the 2 February 2010 indicated an average of 59% ryegrass, 27% white clover and 14% other material (e.g. weeds).

Pasture yield

Olsen P, WSP and pasture yield are shown in Table 1. Pasture yield was affected by method of establishment and pasture type. Although cultivation may have enhanced ryegrass yield via a flush of N, the effect was likely buffered by N applied during the trial. In addition, there was a method of establishment by pasture type interaction with the yield of both the ryegrass monoculture and the mixed sward being less under cultivation than under direct-drilling. This was probably due to the deeper placement of ryegrass seed by the drill in loose, cultivated soil compared to uncultivated soil causing poor establishment. However, the difference in yield due to cultivation was apparent only for cuts 1-3 and 5. For all other harvests there was either no difference or greater yield in the cultivated compared with the direct-drilled plots (Fig. 1).

Figure 1 Mean yield (all treatments) of clover, ryegrass or the mixed sward for the comparison for direct-drill (DD) versus conventionally (Con) cultivated plots. Only significant LSDs (P<0.05 level or better) are indicated.

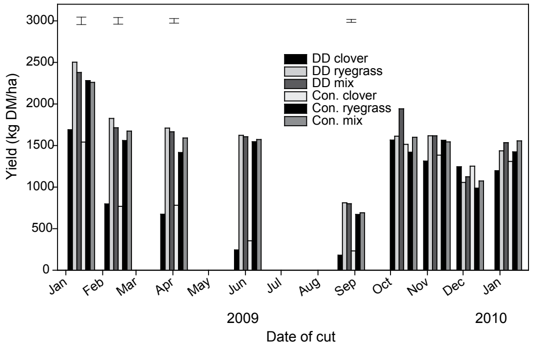
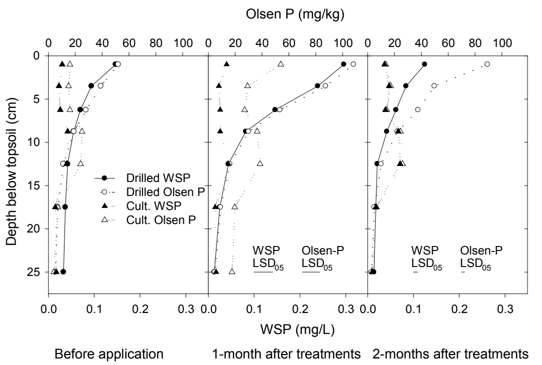


Figure 2 Mean concentration of water soluble P (WSP) and Olsen P with depth in the direct-drilled and cultivated ryegrass-white clover treatment with 35 kg P/ha applied. The least significant difference (LSD_{05}) is for comparison of cultivation treatments with depth.



There was no effect of the rate of P on yield probably as Olsen P concentration was already either optimal or in excess of plant requirements.

Potential for P loss

Before the pasture treatments were established and different P rates applied, both Olsen P and WSP were enriched in the topsoil and concentrations decreased rapidly with depth (Fig. 2). After treatments were imposed the degree of stratification either decreased or increased depending on method of establishment. For example, since the P required to maintain the same Olsen P before treatments were imposed was 30 kg P/ha, those direct-drilled plots that received 100 kg P/ha became more enriched (Table 1). For the cultivated treatments, the concentrations near the soil surface (0-2 and 2-5 cm) tended to decrease.

In addition to a significant response to P application, WSP and Olsen P concentration was less in the 0-7.5 cm of topsoil in plots that had been conventionally tilled compared to those that had been direct-drilled (Table 1). The plough-mixed soil to a depth of 15 cm and the degree of mixing is demonstrated by an equivalent, or slightly greater WSP and Olsen P concentrations from 7.5 to 15 cm depth than from 0 to 7.5 cm depth. This indicates that the potential for P loss to surface runoff from topsoil is likely to be less in cultivated than in direct-drilled plots. Sharpley (2003) found a similar result for recently sown versus established pasture in Pennsylvania, but added the caveat that P loss may be greater in the recently established plots due to poor canopy cover and erosion for the first 20 weeks after sowing. However, in New Zealand, more surface runoff is likely to be associated with winter and not summer rainfall events as in Pennsylvania, thereby allowing more time for good canopy cover in spring-established pasture that would decrease the risk of erosion and P loss.

Among P rates, the 100 kg P/ha treatment enriched topsoil P concentrations, whereas the 35 and 10 kg P/ha applications were designed to maintain clover yield and decrease soil P concentrations to decrease the potential for P loss without compromising yield. Past studies (Gillingham *et al.* 1990; Roberts & Thomson 1988) have established that depending on soil type the proportion of clover and pasture yield can decrease quickly if P is withheld, especially in soil > 30 mg Olsen P/kg. Although our data suggested no decrease in yield from plots receiving 10 compared to 35 or 100 kg P/ha, Gillingham *et al.* (1990) and others showed that when P was withheld, it took up to 3 years for any affect to be evident depending on initial Olsen P concentration. Yield will continue to be monitored in the future to see if it is affected by the likely decline in topsoil P, but as a strategy for decreasing P loss decreasing the application rate is likely to act slower than cultivation.

While the split grass-clover system may have potential to decrease P losses, it should be noted that both cultivation and the use of fertiliser N may increase the N losses compared to a mixed sward especially established by direct-drilling. However, due to the dominance of urine patches as a source of N loss this needs to be investigated further. Nevertheless, the split-grass clover system should be used with caution if in a catchment that is either sensitive to N inputs or used as a drinking water supply.

Conclusions

Modelling of a split grass-clover system for a dairy farm in Southland indicated greater profitability over 10 years than a mixed grass-clover sward. Applying sub-maintenance amounts of P did not affect yield, but as a method for decreasing P loss was not as effective as cultivation, which decreased the concentration of P in the topsoil. Therefore, to establish a split-grass clover system we recommend direct-drilling of clover and cultivation and sowing of ryegrass followed by the application of P at rates to maintain Olsen P as low as agronomically optimal. If ryegrass is placed in areas such as near streams where runoff is likely, the decrease in topsoil Olsen P concentration will likely decrease P loss to waterways.

This represents a quick method of minimising the loss of P to surface waters while improving profitability over 10 years.

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