Forages for Reduced Nitrate Leaching

Monitor farm report

Summary of FRNL dairy monitor farm catch crop demonstration plots

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Forages for Reduced Nitrate Leaching is a DairyNZ-led collaborative research programme across the primary sector delivering science for better farming and environmental outcomes. The aim is to reduce nitrate leaching through research into diverse pasture species and crops for dairy, arable and sheep and beef farms. The main funder is the Ministry of Business, Innovation and Employment, with co-funding from research partners DairyNZ, AgResearch, Plant & Food Research, Lincoln University, Foundation for Arable Research and Manaaki Whenua-Landcare Research.

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1 INTRODUCTION

In the Forages for Reduced Nitrate Leaching (FRNL) programme, a number of experimental trials and desktop modelling exercises in RA2 have tested the effectiveness of catch crops to reduce nitrate leaching losses from autumn/winter-grazed forage cropping systems. Results have consistently demonstrated the benefits associated with the early establishment of catch crops in the Canterbury, Waikato and Southland regions, in terms of reduced risk of nitrate leaching and improved biomass production (Malcolm et al. 2016, 2017; 2018). The next steps were to upscale and demonstrate these novel practices on commercially-operated systems in RA3, to get a better understanding of the potential of catch crops in the context of a real farm system, as well as demonstrate to farmers that this is a valid option to improve the efficiency of nitrogen in their grazed forage crop systems.

In this summary, we report the results of the two years of on-farm monitoring on the FRNL dairy monitor farms, which include sites at St Andrews (Farmer/manager: Chris Rathgen), Mayfield (Farmer/manager: Will Burrett 2017, Nick Giera 2018) and Oxford (Farmer/manager: Sam Lovelock 2017, Jason DeBoo 2018).

Relevant FRNL Milestones that this report relates to:

Activity, Milestone or Deliverable	Start date	End date
1.2.12.A2 Develop research plan and conduct experiments on monitor farms testing winter grazed crops followed by catch crops, monitoring/measuring establishment method, yield, quality, N uptake, residual soil N and use of main crops and of catch crops, and subsequent crop performance (in collaboration with RA2 and 1.3.3). Detailed measurements are combined with practical farm system level monitoring (1.3.3). Submit results to leader of 1.2.10 to compare with modelling results	1-Apr-17	30-Jun-19
1.2.12.D1 Report on experiments on monitor farms testing winter grazed crops followed by catch crops		30-Jun-19

2 METHODS

2.1 Site establishment

Catch crop demonstration plots were established post late autumn/winter fodder beet grazing on three dairy farms within the Canterbury region in 2017 (St Andrews, Mayfield and Oxford), and on two dairy farms in 2018 (St Andrews and Mayfield). Details of each of the sites are given in Table 1. At each of the sites, 10 x 4 m plots were arranged side-by-side within an area of the paddock that had been grazed over a period of no more than 3 days, with a fallow control in the centre, and two catch crop plots on either side. At all sites, the farmers/contractors established the entire paddock with a catch crop, except for the single fallow plot area.

Pre-sowing cultivation (after fodder beet grazing) at the St Andrews site consisted conventional cultivation in 2017 and 2018. At the Mayfield sites, paddocks were cultivated by two passes with a Sumo cultivator and a Cambridge roll in each of the paddocks in 2017 and 2018. At the Oxford site, the ground received two passes with a top-down cultivator with discs. In terms of seeding, all crops were drilled with a conventional seed drill (rates given in Table 1).

Table 1. Details of catch crop plots established at each of the dairy monitor farm sites in 2017 and 2018.

Year	Location	Previously grazed crop	Catch crop treatment	Sowing rate (kg/ha)	Sowing date	Harvest month
2017	St Andrews	Fodder beet	Oats Italian ryegrass	110 25	20 June	November (silage)
			Fallow	-	-	-
	Mayfield	Fodder beet	Oats	120	30 May	September (sprayed)
			Fallow	-	-	-
	Oxford	Fodder beet	Oats Italian ryegrass	110 25	19 June	December (silage)
			Fallow	-	-	
2018	St Andrews	Fodder beet	Oats Italian ryegrass	80 15	27 May	November (silage)
			Fallow	-	-	-
	Mayfield Paddock 1	Fodder beet	Barley	130	14 July	January (grain/straw)
			Fallow	-	-	-
	Mayfield Paddock 2	Fodder beet	Barley	130	31 July	February (grain/ straw)
			Fallow	-	-	-
	Mayfield Paddock 3	Fodder beet	Barley	130	29 August	February (grain/ straw)
			Fallow	-	-	-

Table 2. Fertiliser application details of catch crop paddocks.

Year	Location	Catch crop treatment	Fertiliser applied to catch crop	Amount of fertiliser applied (kg/ha)	Amount of N applied (kg/ha)	Date of application
2017	St Andrews	Oats-Italian RG	Capital effluent mix	100	29	20 Sep 17
	Mayfield	Oats	PhasedN quick start	130	41	23 Aug 17
	Oxford	Oats-Italian RG	N-Protect	80	37	6 Nov 17
2018	St Andrews	Oats-Italian RG	DairyKing	110	20	20 Aug 18
	Mayfield Paddock 1	Barley	Cropzeal 16N	300	45	9 Aug 18
			SustaiN	150	69	15 Sep 18
			Sustain	60	28	21 Mar 19
	Mayfield Paddock 2	Barley	SustaiN	150	69	16 Sep 18
			SustaiN	150	69	4 Oct 18
			SustaiN	60	28	20 Mar 19
	Mayfield Paddock 2	Barley	Cropzeal16	300	45	31 Aug 18
			SustaiN	150	69	16 Sep 18
			SustaiN	150	69	3 Oct 18
			SustaiN	60	28	20 Mar 19

2.2 Measurements

To gain an understanding of the effect of the catch crops on soil mineral N, soil samples were obtained from each of the plot areas post grazing (before sowing), and at the final harvest. Additional samples were taken during mid-growth stages at the Mayfield sites in 2018.

In 2017, soil samples were taken at 0–15 and 15–30 at the Mayfield and Oxford sites, and 0–15, 15–30 and 30–60 cm depths at the St Andrews site. In 2018, sampling depths were the same as those from the previous year at both the St Andrews and Mayfield sites. At each sampling, 10 cores per plot (1 m spacing's along a 10 m transect) were taken. In the field, all the same soil depth samples within each plot were bulked, mixed and sub-sampled for chemical analysis. Samples were then passed through a 4-mm sieve, and a well-mixed subsample of 5 g of sieved soil extracted with 2M potassium chloride (KCl) at a 1:5 soil-to-solution ratio for soil mineral N analysis (NO_3^--N and NH_4^+-N). The filtered extract was analysed for NO_3^--N and NH_4^+-N on a Lachat QuikChem 8500 Series 2 Flow Injection Analysis System (Lachat Instruments, Loveland, CO, USE). Soil moisture content of the samples was measured by weighing fresh subsamples and then reweighing following drying at 105 °C for approximately 16 h or until a constant weight was achieved.

Catch crop biomass samples were obtained at final harvest. This involved harvesting all above-ground biomass material within two randomly placed 0.5 m^2 quadrats of each plot at ground level. Both crop samples were combined to give a total sample area of 1 m^2, and total fresh weight was determined. A subsample of approximately 500 g was oven-dried at 65 °C for approx. 48 hours (or until a constant dry weight was achieved) to determine percentage DM, then finely ground and analysed for total N content using a LECO CNS analyser (LECO Corporation, St Joseph, MI, USA). The product of the DM yield and N concentration in tissue gave the total herbage N uptake on an area basis on each sampling occasion.

3 RESULTS AND DISCUSSION

3.1 Rainfall data

Daily rainfall and cumulative rainfall data for nearest weather stations are given in Figure 1.

Key observations:

- Rainfall patterns between Timaru and Rangiora were similar over the approximate 2-year period, with marginally higher total amounts observed in Rangiora.
- Conditions were generally wetter than normal during the 2017 winter, with particularly high rainfall in July (154 mm in Timaru, and 113 in Rangiora).
- During the winter and early spring months in 2018, rainfall amounts were notably lower than long term averages.

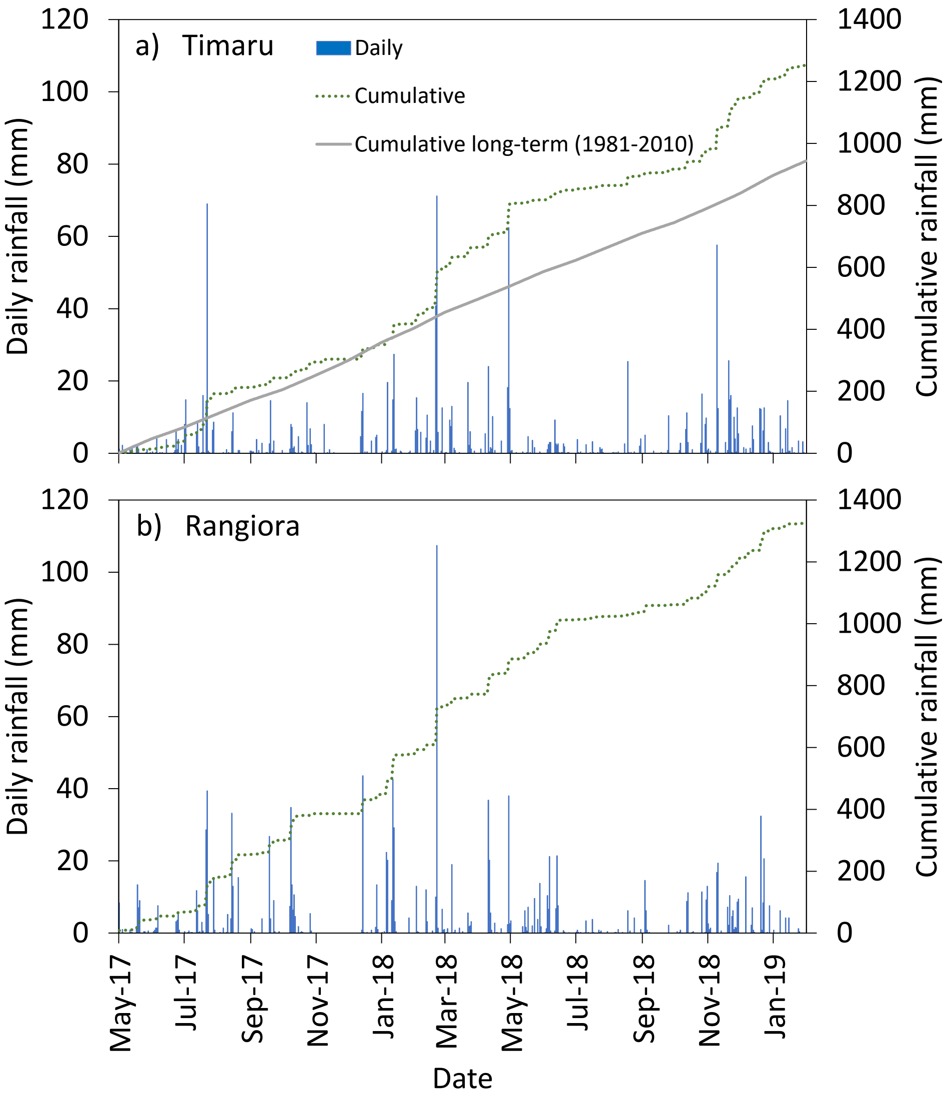

Figure 1 Daily and cumulative rainfall (mm) for a) Timaru and b) Rangiora from 1 May 2017 to 31 January 2019. Long-term weather data was unavailable from the Rangiora weather station.

3.2 Catch crop yield and nitrogen uptake

The amount of accumulated biomass and N uptake from catch crops at the respective monitor farm sites in 2017 and 2018 is presented in Table 3.

Table 3. Yield and nitrogen (N) uptake of catch crops grown on FRNL dairy monitor farms.

Year	Location	Catch crop treatment	Yield (t DM/ha)	N uptake (kg/ha)	ME (MJ/kg DM)	Sample date
2017	St Andrews	Oats-Italian RG	5.9	80	11.1	9 Nov*
	Mayfield	Oats	1.8	53	12.6	19 Oct**
	Oxford	Oats-Italian RG	3.9	36	12.1	7 Nov
			9.7	89	8.4	6 Dec*
2018	St Andrews	Oats-Italian RG	0.6	22	-	13 Sep
			3.4	46	11.2	25 Oct
			7.1	69	11.0	6 Nov*
	Mayfield Paddock 1	Barley	2.2	-	11.9	18 Oct
			11.9	195		6 Dec*
			7.3 (grain)			Jan
	Mayfield Paddock 2	Barley	1.5	-	12.3	18 Oct
			9.7	186		6 Dec*
			7.3 (grain)		14.4	Feb
	Mayfield Paddock 3	Barley	0.4	-	-	18 Oct
			7.5	174		6 Dec*
			7.3 (grain)		14.4	Feb

*final harvest (green-chop), **crop terminated

Key observations:

- All catch crop plots (sown in mid-winter) successfully established and took up N, reducing the risk of N leaching, despite the often wet weather conditions (Fig. 1).
- Final yields at each of the sites in 2017 ranged between 1.8 and 9.7 t DM/ha, with up to 89 kg N/ha accounted for in aboveground biomass. The wide range in yields obtained was due to when the crop was terminated/harvested, e.g. the low yielding crop at the Mayfield site was due to the crop being sprayed early and incorporated as green manure, while other crops were taken through to green-chop silage in November/December.
- In 2018, all crops were taken through to approximately green-chop silage and produced yields of between 7.1 and 11.9 t DM/ha, with 69-195 kg N/ha in aboveground biomass.
- At the Mayfield sites, sowing date had a noticeable effect on yield and N uptake, with higher yields and N uptake observed in the earlier sowing date treatments. This suggests that it is important to sow catch crops at the earliest convenience, even when using barley, which is known to be less winter active than other cereal species.
- Metabolisable energy content of the catch crops at harvest ranged from 8.4–12.6 MJME/kg DM, with the majority of samples measuring above 11 MJME/kg DM (fresh material). At the Mayfield site, quality assessments were done on some grain and whole crop samples in February; ME results were on average 14.4 MJME/kg DM for barley grain, and 11.6 MJME/kg DM for barley grain+straw.

- Additionally, cereal-based catch crops were established after fodder beet grazing on farms in Dunsandel (Canlac Holdings) and Oxford (same farm as 2017) and were consequently sampled for yield and quality. Dry matter yield prior to grazing at Canlac on 9 October 2018 was measured at 2.3 t DM/ha with an ME of 13.2 MJME/kg DM. At the Oxford farm, yields in two of the sampled paddocks on 1 November 2018 were 3.4 and 3.2 t DM/ha at ME's of 12.8 and 13.1 MJME/kg DM, respectively; these crops were subsequently ensiled.

3.3 Soil nitrogen

The amount of soil mineral N in the 0-15, 15-30 and 30-60 (St Andrews only) cm soil depths post grazing and at final catch crop harvest in 2017 is presented in Figure 2. Soil mineral N data in 2018 is presented in Figures 3 and 4.

Key observations:

- In 2017, the amount of soil mineral N in the top 30 cm of soil post grazing ranged from approximately 50-80 kg N/ha; a large majority likely from urine N deposition. By the final samplings (October/November), the amounts of N remaining in the soil profile were generally less, resulting from either leaching, immobilisation, emission or plant uptake.

- In general, there was evidence that catch crops reduced the amount of soil mineral N in the profile at the final sampling, attributed mainly to plant N uptake. For example, except for the St Andrews site, catch crops reduced soil mineral N by 17–35% at final harvest in October/November (Figure 2). Although no difference in soil N was observed at the St Andrews site, 80 kg N/ha was held in the crop biomass, and therefore it is likely leaching losses were significantly reduced under the catch crop.

- At St Andrews in the 2018 season, soil mineral N observed post-grazing were marginally higher than those measured in 2017 (Figure 3). By final sampling in November, the amount of N in the fallow and catch crop plots had decline (as a result of leaching and N uptake). The higher amount of N in the soil under catch crops compared with fallow was unexpected, and may be the result of an unrepresentatively high amount of N in the fallow control (nb: fallow was not replicated), which is indicated at the initial post-grazing sampling in May. In general soil N increased at the 30–60 cm depth over time, indicating leaching of N.

- At the Mayfield sites in 2018, there were notable differences in soil N between the three paddocks/sites (Figure 4). For example, 127–158 kg N/ha was measured in the top 30 cm depths at the post-grazing sampling, compared with no more than 67 kg N/ha in the other paddocks. Interestingly, the later the catch crops were sown the greater the increase in soil mineral N by the October sampling. Increases in soil N were undoubtedly due to mineralisation (and a lack of leaching due to relatively dry spring conditions), suggesting that later cultivations, when soil temperature are more conducive to mineralisation, can increase the amount of N released from the organic pool (via mineralisation), adding to the amount of N at risk of leaching. In other words, earlier cultivation and sowing practices may reduce this risk as a result of cooler soil temperatures, and consequently, lower rates of mineralisation.

- Catch crops reduced residual soil mineral N at the final samplings at the Mayfield sites in 2018, consistent with findings at most of the other sites in 2017.

Photo: Taken within the Oxford site paddock prior to establishment of demonstration plots in 2017.

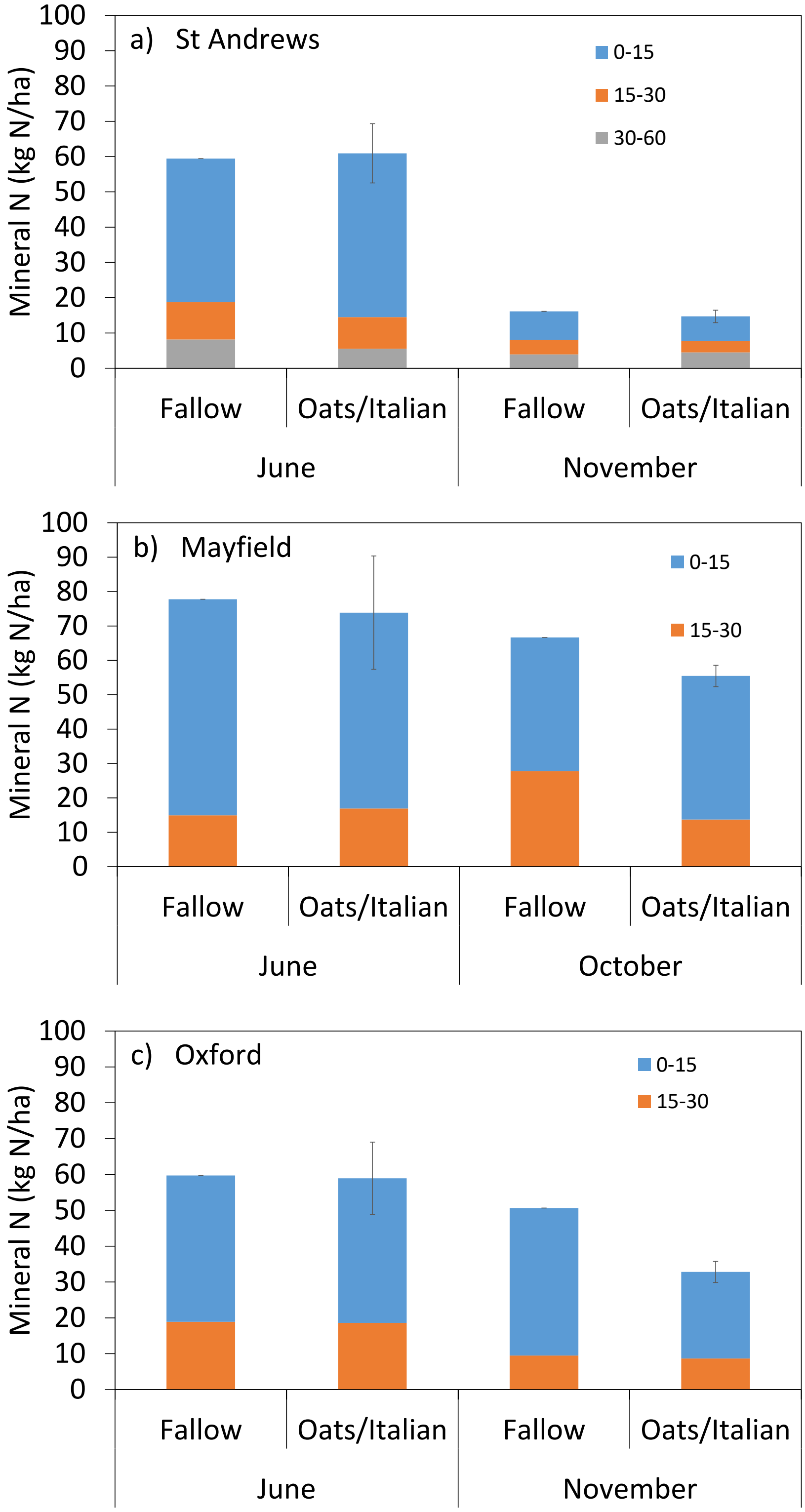

Figure 2 Soil mineral N (kg/ha) of FRNL monitor farm catch crop plots post-grazing (before catch crop sowing) and at final catch crop harvest in 2017.

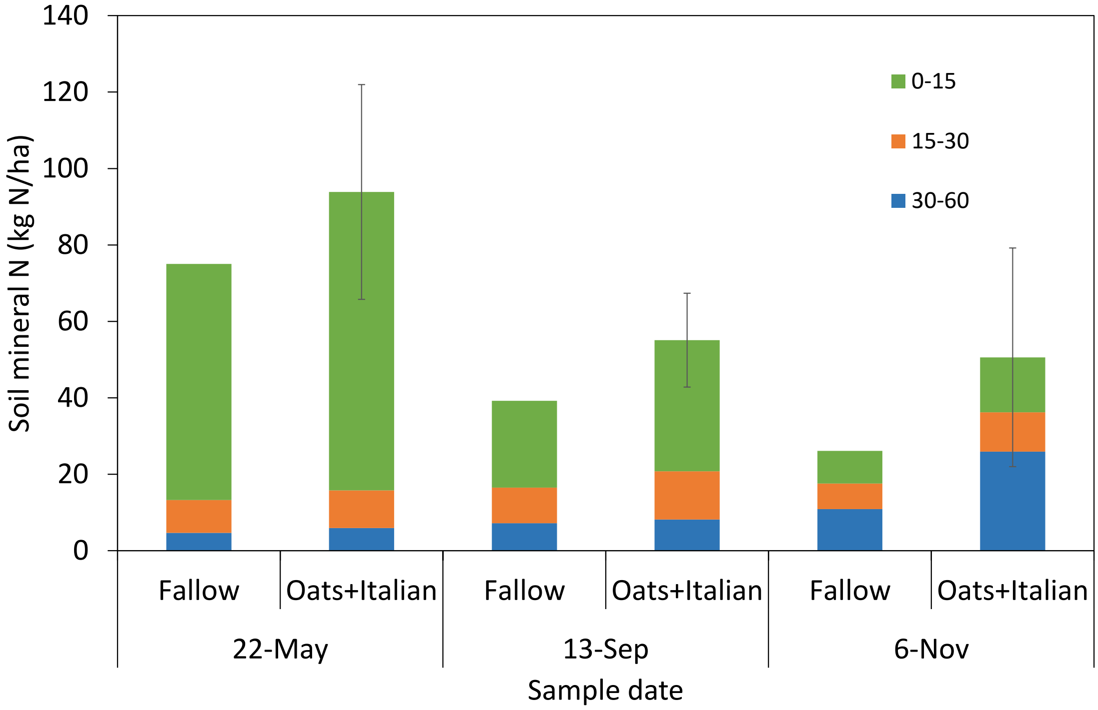

Figure 3 Soil mineral N (kg/ha) of St Andrews FRNL monitor farm catch crop plots post-grazing (before catch crop sowing) and at two catch crop growth stages in 2018.

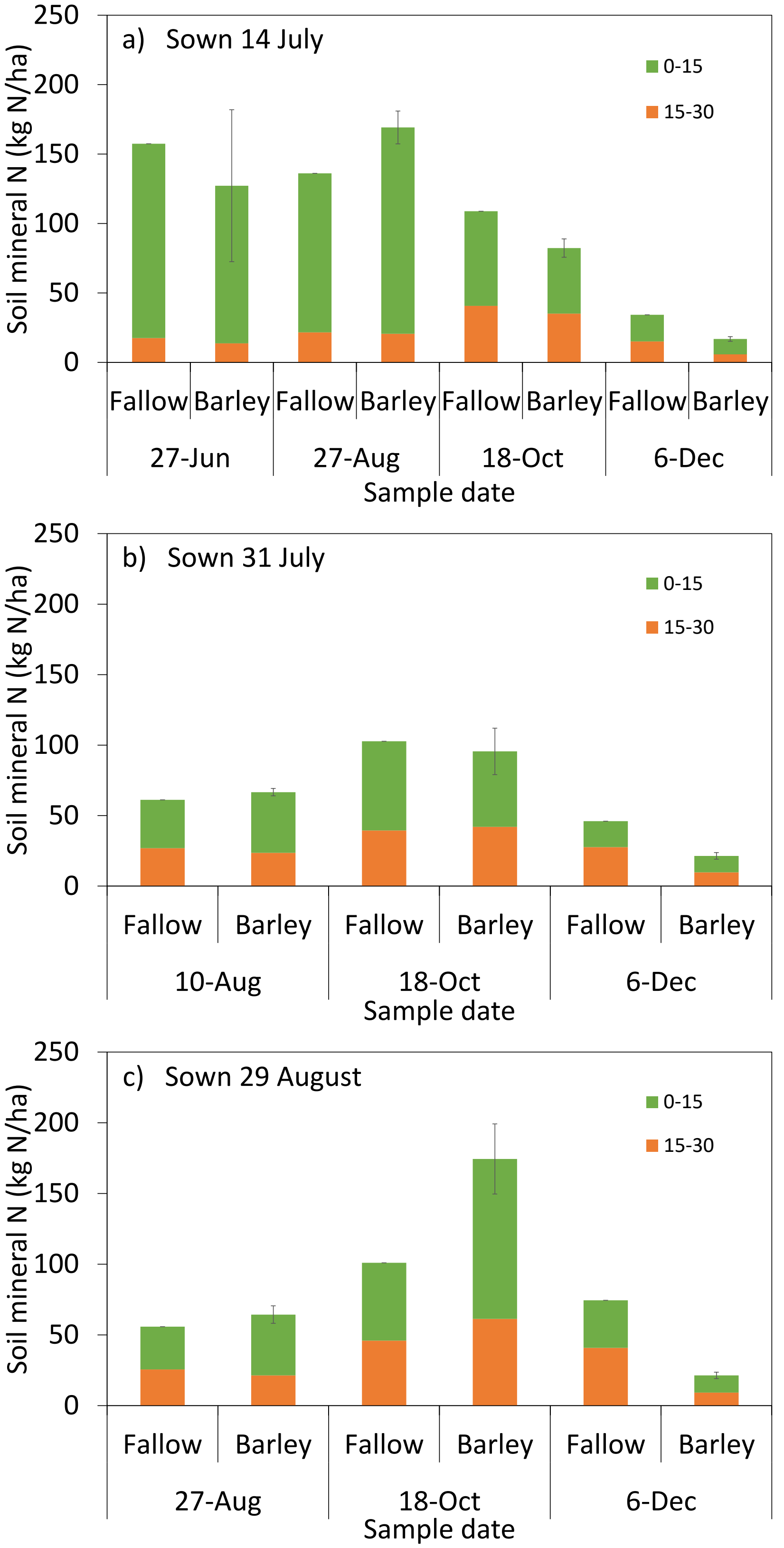

Figure 4 Soil mineral N (kg/ha) of Mayfield FRNL monitor farm catch crop plots post-grazing (before catch crop sowing at three different times; a), b) and c)) and at two catch crop growth stages in 2018.

4 CONCLUSIONS

The main conclusions drawn from this work are:

- Sowing catch crops after grazing in winter is practically possible in the context of a real farm system, and can reduce the risk of N leaching as well as offer high quality additional biomass production (up to 11.9 t DM/ha in the current study).

- The earlier the catch crop is sown post autumn/winter grazing, the better the environmental and productive performance.

- Cereal catch crops successfully sown in winter have the ability to withstand harsh climatic conditions and produce a respectable amount of biomass; however, although in these demonstration plots there were no crop failures, there is still an element of risk, in that in some years, particularly on heavy soils, there is a chance that catch crops might fail due to prolonged periods of cold, water-logged conditions.

5 ACKNOWLEDGEMENTS

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