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New Tillage Technology to Improve Catch Crop Outcomes in Southland

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Abstract

Sowing a catch crop (e.g. oats) after winter forage grazing is a recognised means to limit nitrate leaching losses by removing a significant proportion of the surplus soil mineral-N remaining after grazing. For a catch crop to be effective it needs to be sown as soon as practicable after the cattle have finished grazing, and before the spring, when significant rainfall might reduce their effectiveness.

In the second year (2019) of a three-year NZ MPI/Sustainable Farming Fund transfer project to show the effectiveness and practicalities of incorporating catch crops in commercial dairy wintering operations in New Zealand, it is the Southland region that present the greatest challenge. In Southland many of the winter forage grazing paddocks are on heavy silt loams, and the climate is typically wet and cool, consequently, they are some of the most problematic in the country to manage. Until recently, it has often been too difficult to cultivate or prepare these soils for drilling until mid-to-late spring at best. However, tillage technology that has a reputation for "gentle" soil working (spader plough), even in difficult soil conditions, has enabled the drilling of catch crops over a period when this would have been near impossible under normal practice. The tillage machinery (Farmax Rapide 300 spader, working in combination with an integrated Kongskilde drill; "spader-drill"), represents a new generation of tillage machinery that offers some real mitigation strategies for Southland farmers.

We report the crop emergence, dry-matter yield and N uptake data from two Southland catch crop trials using the spader-drill, compared with conventional minimum tillage, and the potential environmental, efficiency and profitability gains possible in Southland dairy wintering operations.

Keywords

Nitrate leaching, inversion tillage, spader-drill, direct drill, cultivation, oats, Italian ryegrass

Introduction

Winter forage grazing for dairy cattle has been shown to be a major source of nitrate leaching with losses typically ranging from 50-150 kg N/ha (Shepherd *et al.*, 2012; Smith *et al.*, 2012; Monaghan *et al.*, 2013). Sowing a catch crop, such as oats, immediately following winter forage grazing (WFG) has been shown in small plot field trials (Malcolm *et al.*, 2016) and lysimeter studies (Carey *et al.*, 2016; Carey *et al.*, 2017) to significantly reduce nitrate leaching loss. However, Southland farms in winter and early spring represent a real challenge with their cool, wet and often heavy soils so that sowing a crop during this period is particularly problematic. Delaying drilling of a catch crop till the end of September when sol conditions might improve reduces its effectiveness to reduce nitrogen (N) loss and achieve good yields before the need to re-sow a new pasture or forage crop. If farmers aren't confident they will recoup their investment, there will be little incentive to sow a catch crop. Without tillage technology to cope with wet soils, the effectiveness of a catch crop on many Southland winter forage paddocks farms would be limited.

Recent trialling of a Farmax DRP 300 "spader-drill" (Plate 1; supplied by Mr John van Vliet of Balfour), however, showed it could cope successfully working in moderately wet and heavy soils and drill a crop at the same time. This presented an opportunity to test it in the Southland winter forage catch crop programme. This active tillage machine uses the power take-off (PTO) shaft of the tractor to operate the spader-drill. In effect, the rotating spades push the tractor forward, rather than the tractor pulling the spader-drill. The spader's action is an incomplete form of inversion tillage compared to an inversion plough (not possible on a wet, heavy soil), but by burying the bulk of the wetter soil from the surface (to a depth of ~25 cm), and bringing up drier soil, means the soil can be harrowed and subsequently, drilled, in a one-pass operation. Such technology may be a game-changer for the region and could incentivise Southland farmers to mainstream catch crops as an integrated part of their winter forage rotations.

The objectives of this work were to i) test the effect of two different establishment methods (spader-drill vs conventional minimum cultivation and drilling) and seeding mixtures of catch crops on reducing the risk of N leaching losses compared to fallow soil, and ii) assess outcomes on two contrasting soil types.

Materials and Methods

Trial sites

The Southland trial sites were located on winter forage paddocks near Lumsden (-45.7617, 168.4692) and Mossburn (-45.6844, 168.2771; Figure 1). Some soil and crop characteristics associated with each site including available soil mineral-N are shown in Table 1.

Table 1. Site and soil classification for each trial site.

Trial site	WFC [a]	Soil name (drainage/texture)	NZSC [b]	Soil depth (cm)	Vol. stone content (%)	MN [c] kg/ha
Mossburn	Fodder-beet	Morven (well drained, shallow silt loam)	Brown	0-15	40	48
				15-30	38	29
Lumsden	Kale	Eureka orthic acid gley (poorly drained, (mod. deep silt loam)	Pallic	0-15	0	120
				15-30	8	41
				30-60	18	42

[a] Winter forage crop prior to trial establishment; [b] New Zealand soil classification, [c] Mineral nitrogen = total ammonium + nitrate, representing mean available mineral-N resident at each site on 11 July, 2019. Method modified from Blakemore et al. (1987).

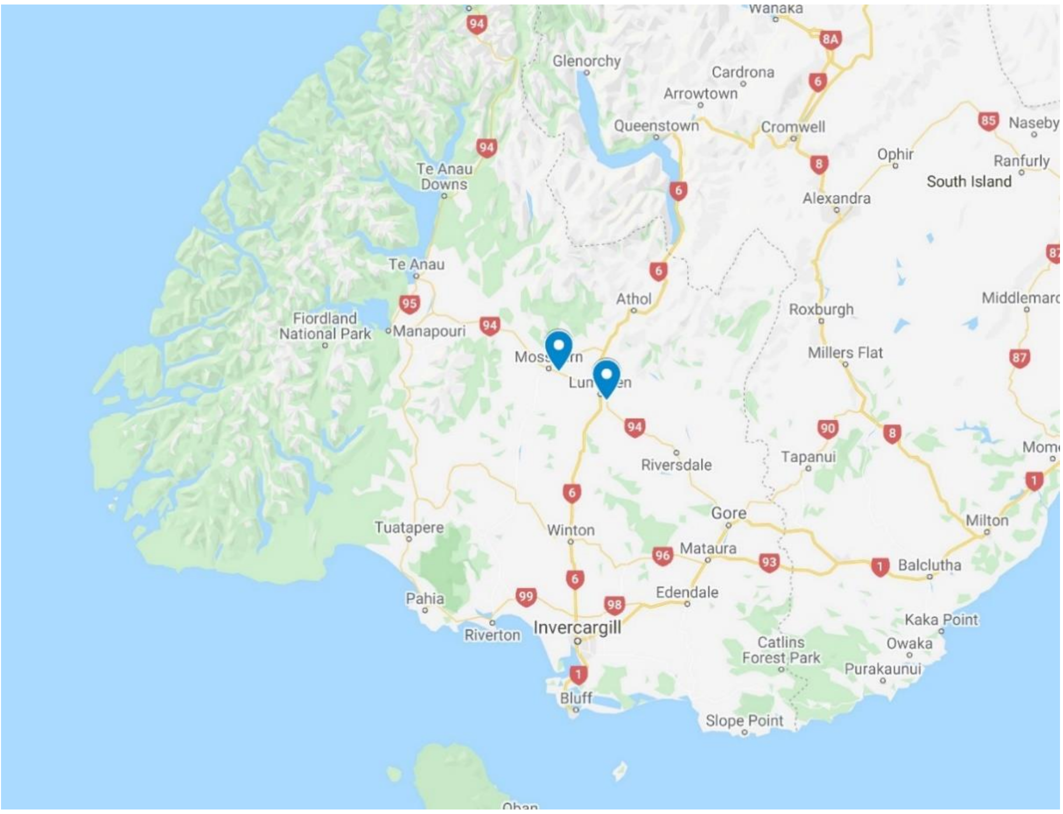

Figure 1. Location of Southland trial sites.

Plate 1. Farmax DRP 300 spader-drill unit shown on back of tractor.

Treatments

Each tillage or crop species trial plot was 6 m wide and 10 m long, with the fallow plots 3 m wide left undisturbed. Both trials in Southland followed the same tillage treatment format comparing fallow with a minimum/direct drill or spader-drill treatments (Plate 2). At the Lumsden trial a comparison was also made between oats-only (Milton) and an oats+Italian ryegrass (Asset) mix in a 2x2 factorial with the cultivation treatments plus fallow. Treatments are outlined in Table 2 with tillage and harvest dates. Drilling rates for oats were set at 110 kg/ha, (target plant population 300 plants/m^2) and for the oats/Italian ryegrass mix at 70/20 kg/ha, targeting 200 and 400 plants/m^2, respectively. Only the oats-only treatments are reported.

Table 2. List of trials and treatments (IR = Italian ryegrass)

Trial	Factor	Treatment	Tillage & harvest dates	Tillage equipment
Mossburn (ex-fodder beet)	cultivation	Fallow	-	
		Spader-drill	Cultivated/drilled Jul 11	Farmax Rapide 300 DRP Kongskilde drill (3m)
		Minimum till/direct drill	Cultivated/drilled Aug 3	Direct drill (Taege drill -3 m)
			Harvested Dec 12	
Lumsden (ex-kale)l	species x cultivation	Fallow	-	
		Oats/spader-drill	Cultivated/drilled July 11	Farmax Rapide 300 (3 m) Kongskilde drill
		Oats-IR/spader-drill		
		Oats/minimal till/direct drill	Cultivated/drilled Sep 9	Ripper (no make) 11 leg -3 m + Duncan drill
		Oats-IR/minimum till/direct drill		
			Harvested Dec 12	

Measurements and data analysis

Climate measurements (air temperature-Campbell Scientific CS107, soil temperature CS107B at 10 cm depth and rainfall-tipping bucket rain gauge, 0.2 mm resolution) were collected using a CS CR10X data logger from the Mossburn site and compared with long-term data from nearby NIWA climate stations at Mossburn (5-years data only), Lumsden (no soil temperature data) and Gore. Soil temperature data (5 cm depth) was also recorded hourly for the duration of each trial using soil temperature "buttons" (IButton Thermochron F5-Maxim Integrated) placed in the fallow plots.

Plant counts were carried out for both trials in August 2019 involving three random 1 m counts for each plot. Dry-matter (DM) cuts were taken three times for each trial (16 Sep, 7 Nov and 28 Nov) through the growing period and samples taken for moisture (dried at 60°C) to calculate DM yield and for total-N analysis, using a LECO CNS analyser (LECO Corporation, St Joseph, MI, USA).

Gross profit margins and associated economic variables were calculated using DM yield price and costs of production as provided in the "Financial Budget Manual" information for the South Island of NZ as provided by Askin and Askin (2018).

Statistical analysis was done by general ANOVA using Genstat 18th (VSN International Ltd., 2018) testing for main effects between tillage treatments at both sites and interaction effects with crop species at Lumsden. Duncan's multiple range lettering test was used to denote significant differences at the 5% level between treatments using uncommon letters.

Plate 2. Comparison of fallow (left) and Farmax DRP 300 spader-drill plots (right) taken one month after drilling (11 Jul, 2019).

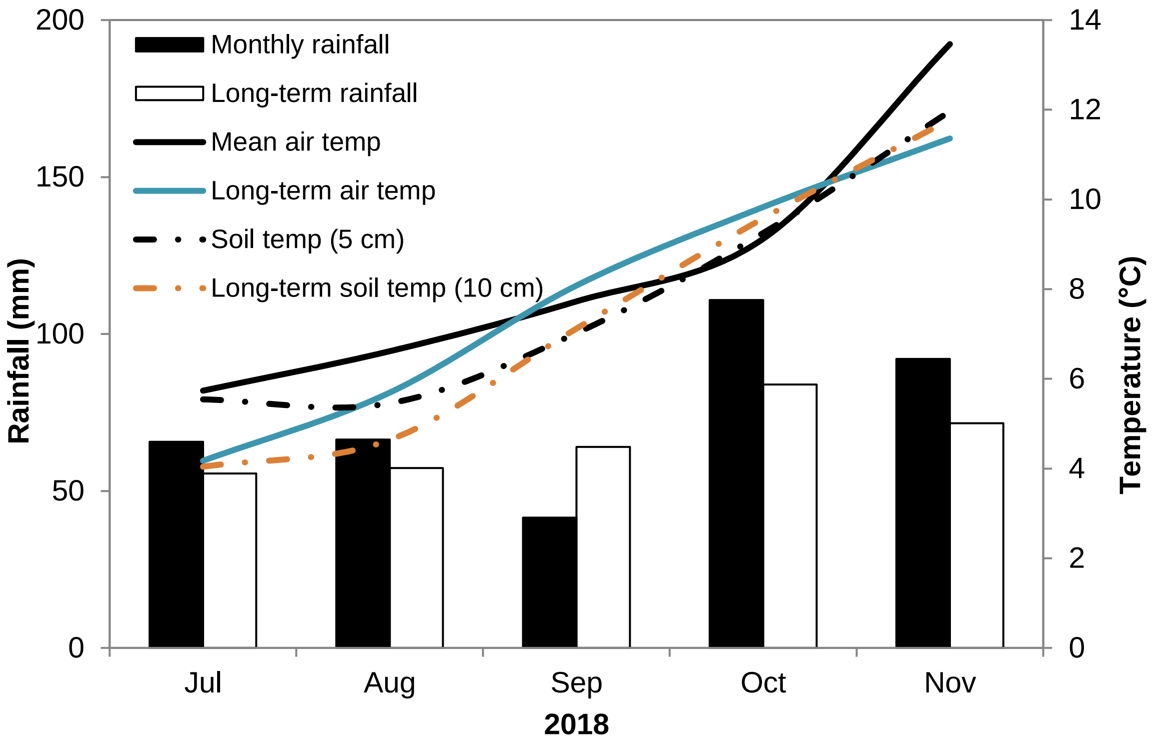

Figure 2. Weather data for 2019 Southland trials compared with long-term means (1990-2019) from local NIWA climate stations and on-site recording.

Results

Weather

Mid-winter 2019 (July) in the Mossburn-Lumsden region was considerably warmer (by ~1.7°C) and slightly wetter than average but rainfall and temperatures approached the long-term average by the onset of spring in September (Figure 2). October and November were notably wetter than average (~30% more rainfall) with November in particular proving a particularly warmer than average month (~1.5°C higher), although soil temperatures remained near the long-term average.

Crop emergence

Oats sown in July (spader-drill plots only) emerged well, and within a month after drilling, but somewhat variably between trial sites. Emergence rates for tillage treatments of both trials were, on average, well less than the target of 300 plants/m^2. At Lumsden, spader-drill plots fared worse than cultivated plots (125 vs 162 plants/m^2) but at Mossburn, germination rates were generally better for the spader-drill plots than the direct drill plots (190 vs. 165 plants/m^2, respectively).

Dry-matter production and N uptake

The early drilling of the spader-drill plots (by up to eight weeks difference) meant these got off to a good start and, unsurprisingly, their DM yields remained significantly ($P<0.001$) ahead over the minimum till treatment plots right through to harvest at the end of November when DM yields were ~8 t DM/ha for both trials (Figures 3A and 4A; oats-only, no N applied). Despite lower emergence rates for the spader-drill treatments at Lumsden this was not a significant factor for DM yields overall. The earlier start for the minimum till (direct-drill) treatment at Mossburn (3 Aug) than at Lumsden, (9 Sep) meant that by the first harvest (Oct 15) there was a DM yield of ~0.4 t/ha but this was barely a third of the DM yield for the spader-drill treatment. Total DM yields were overall greater for the Oats-only treatments over the combined oats-Italian treatments, but not statistically significant (data not presented).

The difference in DM yields was complemented by N uptake, where at final harvest, spader-drill treatments (65-94 kg N/ha) had significantly greater N uptakes over the minimum till treatments (35-72 kg N/ha; $P<0.01$). This represented 46% and 83%, of the soil available mineral-N initially present in the spader-drill plots, at the Lumsden and Mossburn trials, respectively, but only 35% and 44% for the minimum till plots, respectively. However, for the spader-drill treatments, most of this N was taken up in the critical early-to-mid spring (Oct/Nov) period (Figures 3B and 4B; oats-only, no N applied). Strong symptoms of N deficiency were displayed in the oats crop, by mid-October in the Mossburn trial, and by early November at Lumsden, indicating a strong case for a strategic N application at this time to achieve maximum quality and quantity.

Net gross profit analysis

Crop yields of ~8 t DM/ha were particularly profitable for the spader-drill treatments with net gross profits (NGP) exceeding $1400 per ha on average (range $1252-$1611/ha; Table 3). Costs associated with the spader-drill also worked out less overall because only one pass was required to till and drill the soil where even minimal tillage might require three operations (ripper/harrow/drill) in order to break the compacted soil layers, prepare a seed bed and sow the crop. The minimum till treatment was still profitable but at a NGP of ~$400/ha, was less than a third of that for the spader-drill treatment. Minimum till is more dependent on consecutive fine days to complete, and thus, bad weather can delay operations, reducing the NGP margin further. Although spader-drill operation is slower (1-1.5 ha/hour), it can do a 7-8 ha paddock in a day, only a short-window of opportunity is necessary for the crop to be sown.

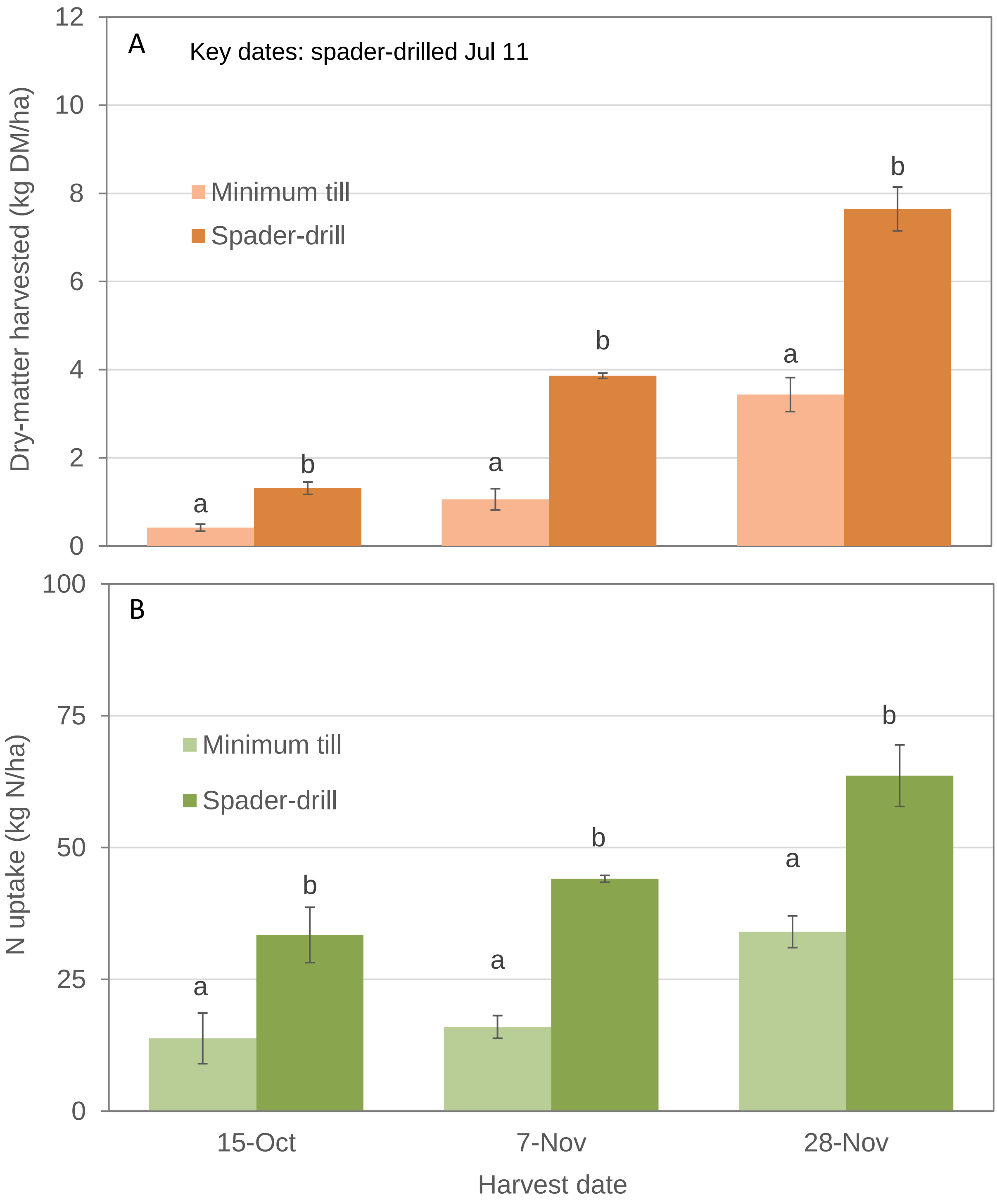

Figure 3. **Mossburn dry-matter yield and N uptake for spader-drill and direct drill treatments for oats-only plots (no N applied). Uncommon letters denote significant differences within individual harvest dates at the 5% level (Duncan's multiple range test).**

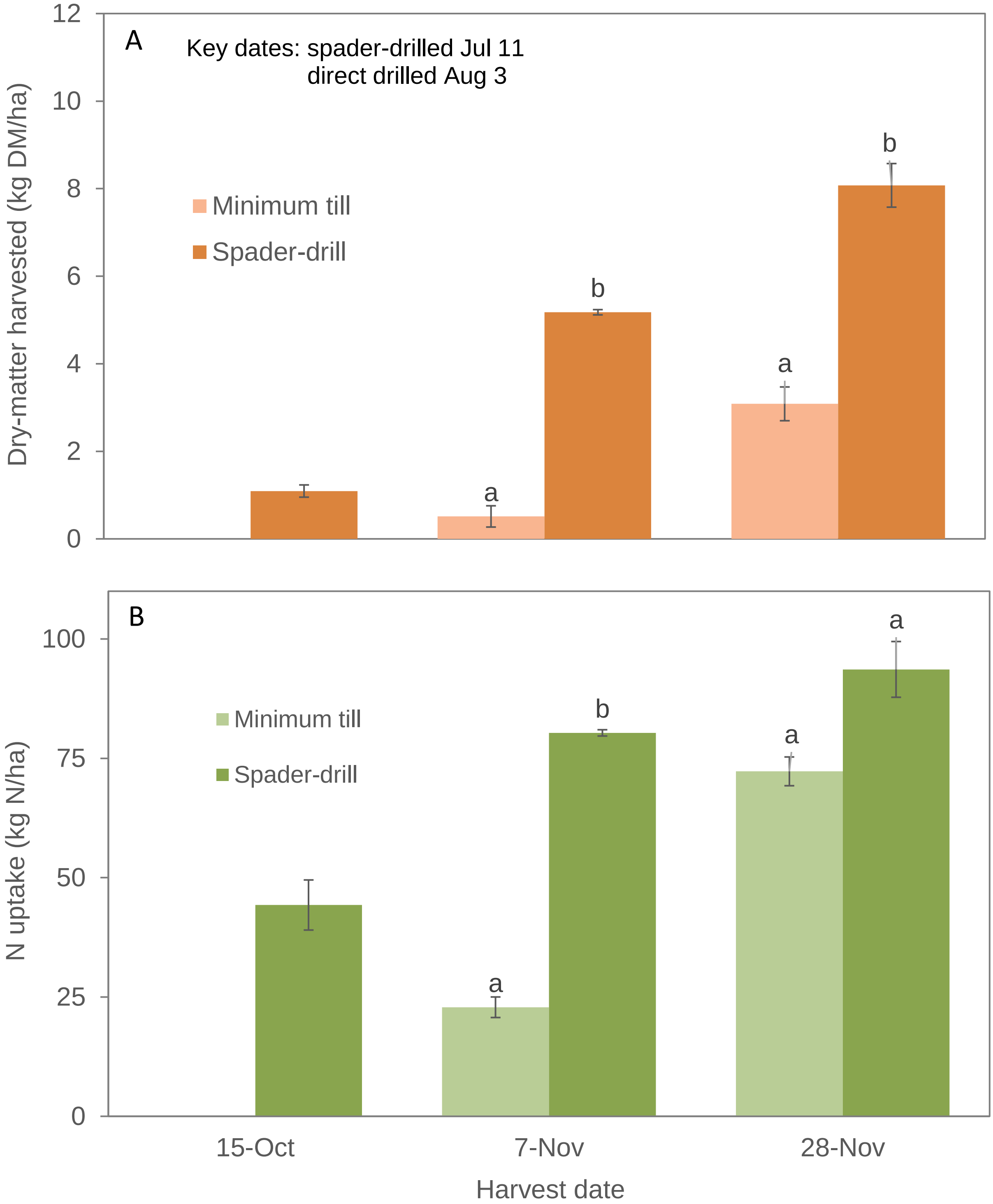

Figure 4. **Lumsden dry-matter yield and N uptake for spader-drill and direct drill treatments for oats-only plots (no N applied). Uncommon letters denote significant differences within individual harvest dates at the 5% level (Duncan's multiple range test).**

Table 3. Gross profit margins and associated economic variables for Mossburn and Lumsden tillage/species trials (IR= Italian ryegrass) (Askin & Askin, 2018).

Trial site	Drilling Treatment	Crop	Yield t DM/ha	Revenue $/ha	Inputs $/ha	Cost c/kg DM	Margin $/ha	Profit c/kg DM
Mossburn	Spader-drill	Oats	7.6	1900	453	5.9	1446	19.0
	Direct-drilled	Oats	3.4	850	253	8.2	597	17.6
Lumsden	Spader-drill	Oats	8.1	2025	414	5.1	1611	19.9
	Spader-drill	Oats+IR	7.0	1750	497	7.1	1252	17.9
	Minimum till	Oats	3.1	775	414	13.4	360	11.6
	Minimum till	Oats+IR	3.1	775	497	16.0	278	8.9

Discussion

The advantage of a catch crop in a grazing rotation is not only the extra feed that it brings, but the second chance it also offers should the main winter forage not meet expected yield, for example, because of delays in drilling. Using a spader-drill means the sowing of the catch crop can usually occur soon after the cessation of animal grazing and although spader-drill operation is slower (1-1.5 ha/hour; 7-10 ha per day) only a short-window of opportunity is necessary for the crop to be sown. Despite the spader-drill plot emergence rates at Lumsden being lower than for the minimum till treatments, probably explained by the wet, cool soil bed conditions at this time, they maintained a significant DM yield advantage right through to harvest. In fact all oats treatments at both trial sites had lower emergence rates than the targeted 300 plants/m^2 and there may be a case for increasing sowing rates to compensate to get faster canopy closure. Nevertheless, the yield advantage from sowing at this time was evident in both trials with the catch crops from the spader-drill treatments producing twice as much feed (NGP ~$1400/ha vs. ~$500/ha) as well as removing 30-48% more soil mineral-N (65-94 kg/ha). Results were similar to those obtained at Gore in 2018, the previous year, where DM yields (8.4 vs. 4.5 t/ha) and N uptake (124 vs 96 kg N/ha) for the spader-drill over the minimum tillage treatments were 87% higher and 30% higher, respectively, and with similar levels of profitability(Carey *et al.*, 2019). Higher amounts of N in the crop at final harvest have been reported in other studies (up to 240 kg N/ha; Malcolm et al. 2016), but these have generally been within the confines of a non-grazed, simulated urine patch condition. In both 2018 and 2019 Southland trials, plots cover both urine and non-urine treated areas that are more aligned (albeit lower) with those from an on-farm trial in Canterbury following grazed fodder beet and kale, where uptakes of 132 and 98 kg N/ha, respectively, were reported in the crop at final harvest in November 2016 (Malcolm *et al.*, 2017).

Although it was possible to sow plots by way of direct drill, and only three weeks later than the spader-drill treatments at Mossburn, the spader-drill produced a superior seed bed that, in combination with warmer-than-average soil temperatures, got the catch crop off to a strong start at both sites. This produced early gains in DM production and N uptake so that by Nov 7, 54-64% of the DM yield at harvest, and 69-86% of the N uptake, was already in the spader-drill treatments but only 16-32% and 31-47%, respectively, for the minimum till treatments. The ability of the spader-drill to work reliably in wet soil conditions confers this advantage and seems to be for no more detrimental effect on soil physical condition although this is still to be adequately tested. To date, recorded average soil bulk density of 0.89 g cm^{-3} and macroporosity of 23.1% for the spader-drill pots at Lumsden at harvest is much higher than the New Zealand target of 10.0%, at 0–7.5

cm (W. Hu; personal communication).

The N retained in the spader-drill treatment catch crops from the Mossburn and Lumsden trial sites represented around 50%-80% of the initial available mineral-N resident in the soil profile (Table 1), respectively; N that might otherwise have been lost in leaching, runoff and/or denitrification. Higher than average rainfall through October and November and high soil moisture conditions made the prospect of nitrate leaching more likely from the fallow plots so N taken up over this critical period is protected from loss. Previous catch crop research in Canterbury lysimeter and field studies has shown that sowing a catch crop can reduce N leaching losses and soil mineral-N content by between 19-49% and 53-86%, respectively, compared with fallow treatments (Carey et al., 2016; Malcolm et al., 2016; Malcolm *et al.*, 2020). However, as with these trials, and those from the earlier Canterbury research and the previous year's (2018) Southland trials, the effectiveness (and profit) of sowing the catch crop is greatest when it is sown as soon as possible following the cessation of winter grazing (Carey et al., 2016; Malcolm et al., 2016; Carey et al., 2019).

Conclusions

These trials validate last year's Southland winter forage catch crop research (Carey et al., 2019) and demonstrates to farmers that tillage technology such as the Farmax spader-drill can make a significant difference to good catch crop establishment. Farmers can have the confidence to sow a catch crop because of its ability to work in wet soil environments, despite the relatively short window of opportunity, and this is important to encourage the sowing of catch crops. Where drilling occurs sufficiently early, the probability of success is high and very profitable.

Just as importantly, inserting a catch crop in a winter forage rotation can lift the environmental performance of a Southland dairy wintering operations for no cost, in effect a "win-win" situation. In an era of increasing environmental scrutiny of farming operations, it is timely to offer farmers an opportunity to improve environmental outcomes without an impost on the farm budget.

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References

Askin, D. & Askin, V. (eds) 2018. *Financial Budget Manual,* Faculty of Commerce, Lincoln University, Lincoln University.

Blakemore, L. C., Searle, P. L. & Daly, B. K. 1987. Methods for Chemical Analysis of Soils. NZ Soil Bureau, Lower Hutt., pp. 103

Carey, P., Malcolm, B. & Maley , S. 2019. COI Group: Catch crops for reduced nitrate leaching 2018. (ed P. Carey), Lincoln Agritech, Lincoln, Canterbury, pp. 18

Carey, P. L., Cameron, K. C., Di, H. J. & Edwards, G. R. 2017. Comparison of nitrate leaching from oats and Italian ryegrass catch crops following simulated winter forage grazing: a field lysimeter study. *New Zealand Journal of Agricultural Research,* **60,** 298-318.

Carey, P. L., Cameron, K. C., Di, H. J., Edwards, G. R. & Chapman, D. F. 2016. Sowing a winter catch crop can reduce nitrate leaching losses from winter-applied urine under simulated forage grazing: a lysimeter study. *Soil Use and Management,* **32,** 329-337.

Malcolm, B., Teixeira, E., Johnstone, P., Maley, S., de Ruiter, J. & Chakwizira, E. 2016. Catch crops after winter grazing for production and environmental benefits. *Proceedings of the Agronomy Society of New Zealand,* **46,** 99-108.

Malcolm, B., Teixeira, E., Johnstone, P., Maley, S., de Ruiter, J. & Chakwizira, E. 2017. Establishment methods of oat catch crops after winter forage grazing. *Agronomy New Zealand,* **47,** 65-77.

Malcolm, B. J., de Ruiter, J. M., Dalley, D. E., Carrick, S., Waugh, D., Arnold, N. P., Dellow, S. J., Beare, M. H., Johnstone, P. R., Wohlers, M., Brown, H., Welten, B. & Horrocks, A. J. 2020. Catch crops and feeding strategy can reduce the risk of nitrogen leaching in late lactation fodder beet systems. *New Zealand Journal of Agricultural Research,* **63,** 44-64.

Monaghan, R. M., Smith, L. C. & de Klein, C. A. M. 2013. The effectiveness of the nitrification inhibitor dicyandiamide (DCD) in reducing nitrate leaching and nitrous oxide emissions from a grazed winter forage crop in southern New Zealand. *Agriculture, Ecosystems & Environment,* **175,** 29-38.

Shepherd, M., Stafford, A. & Smeaton, D. 2012. The use of a nitrification inhibitor (DCn™) to reduce nitrate leaching under a winter-grazed forage crop in the Central Plateau. In: D. Swain ed. Opportunities of Changing Land Use. New Zealand Grassland Association. Gore. 74: 103-107.

Smith, L. C., Orchiston, T. & Monaghan, R. M. 2012. The effectiveness of the nitrification inhibitor dicyandiamide (DCD) for mitigating nitrogen leaching losses from a winter grazed forage crop on a free draining soil in northern Southland. In: D. Swain ed. Opportunities of Changing Land Use. New Zealand Grassland Association. Gore. 74: 39-44.

VSN International Ltd. 2018. GenStat for Windows 18th Edition. In., VSN International, Hemel Hempstead, United Kingdom, https://www.vsni.co.uk/.