Guidelines

May 2024

Catch Crops for Reduced Nitrate Leaching

Lessons from the "Forages for Reduced Nitrate Leaching" programme, Sustainable Food and Fibre Futures project "Catch Crops to Reduce Nitrate Leaching" and Sustainable Land Management and Climate Change – Freshwater Mitigation project "Catch Crops for Cleaner Freshwater".

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Winter forages such as kale, swede and fodder beet are important single-graze species for livestock. This guide focuses on the use of catch crops after forage crop grazing to take up nitrogen (N) during the coolest months of the year. It aims to explain the whys and hows to help manage your expectations and decision making.

Forages for Reduced Nitrate Leaching (2013–2019) was a DairyNZ-led collaborative research programme across the primary sector delivering science for better farming and environmental outcomes. The aim was to reduce nitrate leaching through research into diverse pasture species and crops for dairy, arable and sheep and beef farms. The main funder was 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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What is a catch crop?

A catch crop is any crop that is grown with the primary objective of mopping up excess nitrogen (N) in soils, which may otherwise be lost through leaching as nitrate. The reduction in nitrate leaching losses results from the crop's rapid uptake of residual mineral N and the reduction of the water content of soil, which reduces the risk of drainage.

The primary objectives of catch crops are to:

- Reduce nitrate leaching losses during high risk periods
- Increase annual dry matter production
- Aid soil restoration

Importantly, the effectiveness of catch crops varies between sites and years, and depends on climate, soil and management factors. The influence of these factors on catch crop performance is discussed below.

What is the difference between a catch crop and a cover crop?

The terms "catch crops" and "cover crops" are often used interchangeably, however, technically, they are different. "Cover crop" is an umbrella term that includes all crops grown to 'protect or improve' between periods of regular crop production. Cover crops provide a range of functions such as weed suppression, organic matter returns, surface soil protection and capturing N that may otherwise be vulnerable to leaching. A cover crop sown with the primary purpose of reducing nitrate leaching is referred to as a "catch crop".

Oat catch crop after winter grazed fodder beet

Common reasons for use of catch crops

In a recent survey of farmers from all sectors, **environmental** benefits were the main reasons cited for planting catch crops. Other benefits identified, in order of ranking, were **additional feed, ground cover** and **organic matter returns**. These are discussed below.

Environmental benefits

Nitrate leaching and sediment/contaminant runoff are naturally occurring process. When excess N (fertiliser and/or urine N) and exposed soil (including phosphorus and *E-coli*) is lost via leaching or runoff during rain/drainage events, not only is it a loss of valuable nutrient from the farm system, it can pollute both ground and surface water. This pollution is the focus of national and regional government strategies to improve water quality.

Nitrogen from fertiliser or urine can be problematic because when added to the soil, a large proportion is converted to nitrate (NO_3^-) which is especially susceptible to leaching (Figure 1). This conversion process is known as "nitrification". Nitrification occurs relatively slowly in winter, offering a window of opportunity for catch crops to capture some N before it is lost through leaching.

Runoff plots in Southland

Catch crops sown after winter grazing can take up significant quantities of N (Figure 2) and reduce N leaching losses by up to 50% (Figure 3). In addition, winter-sown catch crops have also been shown to significantly reduce the risk of sediment runoff (by >40%) and sediment-associated phosphorus runoff.

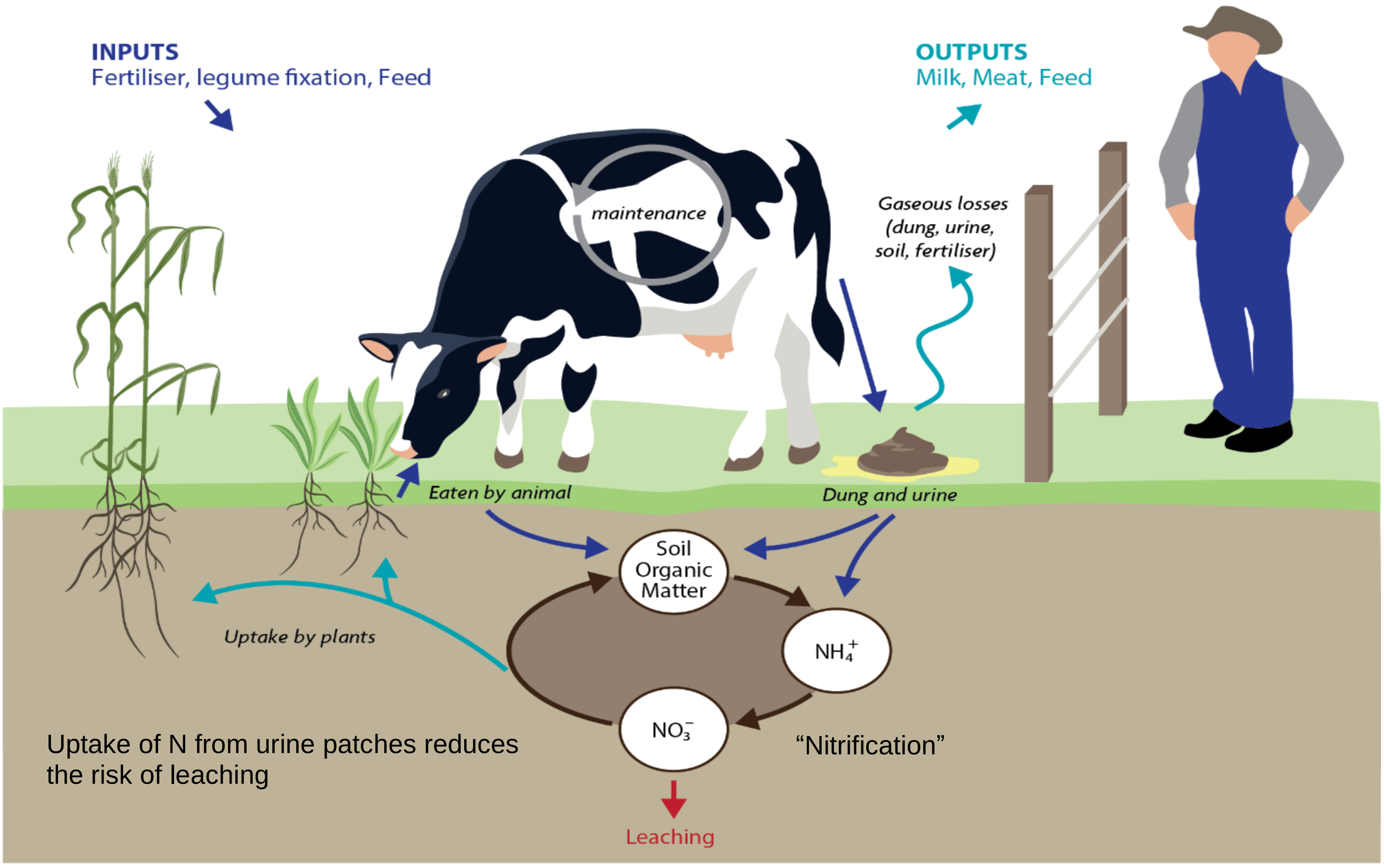


Figure 1. The nitrogen cycle.

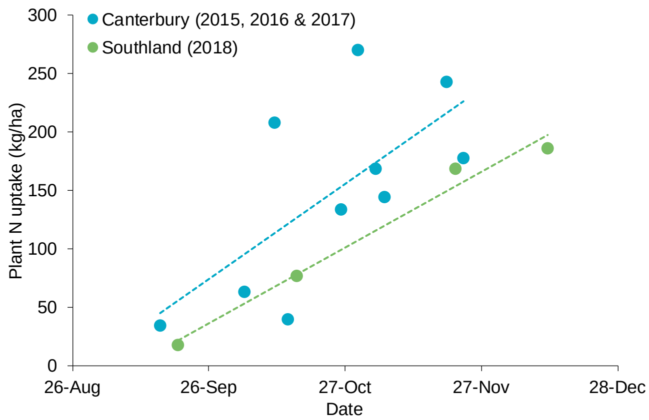


Figure 2. Plant nitrogen (N) uptake of oat catch crops sown in late June/early July after simulated winter grazing (2015–2018), Canterbury and Southland.

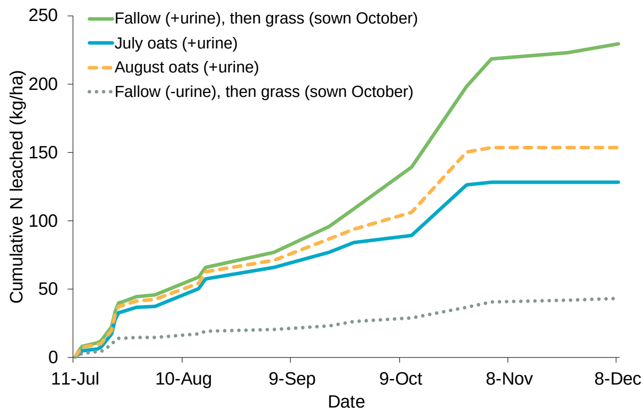


Figure 3. Cumulative mineral nitrogen (N) leached in a wet year from a light soil, following artificial urine deposition, after sowing of an oat catch crop in early July or August, Canterbury.

Catch crop leaching experiment, Southland

How much N is typically lost after winter grazing?

If soils are left fallow for several months following the winter grazing of forage crops like kale and fodder beet, there is a high risk of nitrate leaching from large numbers of urine patches deposited during grazing. This is because rainfall normally exceeds evapotranspiration in winter and early spring, resulting in soil drainage and nutrient loss. Losses typically range from 50–180 kg N/ha, which is a risk to the environment and an expense to the farm business.

Additional feed and dry matter production

Establishing a catch crop after winter grazing can offer additional forage production per hectare, and in turn, higher farm productivity.

Trials in Canterbury found that oats sown in July after winter-grazed fodder beet or kale could produce yields of between 6 and 12 t DM/ha (e.g. refer to Figure 4) by 24 November at relatively low cost (<$0.11/kg DM).

Timing of harvest can have important implications for productivity and crop quality, especially metabolisable energy (ME). Generally, for oats the ideal time to harvest is at green-chop silage maturity (growth stage 45-52). After the green-chop silage maturity stage, stem growth and fibre production cause a temporary reduction in the overall feed value. Delaying harvest time beyond the green-chop silage maturity stage results in an initial decline in ME per kg of DM, and then an increase as starch is stored during grain filling.

More information about catch crop yields can be found in the section **What sort of catch crop is best and when is it too late?**

Additional information on oat yield in rotation with kale can be found in the DairyNZ Factsheet *Sequence cropping kale and oats*.

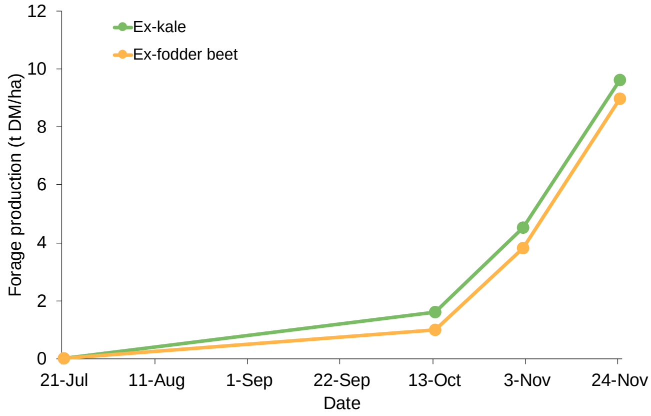


Figure 4. Forage production of oat catch crops sown in mid-July 2016 after winter grazed fodder beet and kale on Balmoral/Lismore stony silt loam at Lincoln University's Ashley Dene Research and Development Station.

Reducing imported supplement

For dairy and dairy support operations, the ability of catch crops to reduce nitrate leaching on the milking platform or dairy support block is affected by how the extra feed generated by the catch crop is used. If the catch crop is harvested and used to increase both the amount of feed offered and the stocking rate, it may not reach desired outcomes at a whole farm scale. The benefits for reducing N leaching are maximised where the catch crop is used to both mop up N that is at risk of leaching, and to reduce reliance on imported feed and associated imported N. Overall, this will help to reduce the N surplus, which is the balance between N inputs (imported supplement N and fertiliser N) and N outputs (N lost in milk, meat, wool, crops etc.).

Ground cover

Catch crops provide important ground cover that can reduce the risk of soil loss due to runoff. Runoff represents a loss of an important resource (e.g. soil organic matter and nutrients) and also contributes to negative downstream impacts such as flooding and sediments in waterways.

Catch crop trial post fodder beet, Canterbury (oats vs fallow-pasture)

Table 1. 2018 catch crop trial treatments and biomass production harvested at approx. green chop (beginning of November 2018) or at approx. whole crop silage stage (end of December 2018).

Catch crop/s (and cultivar)	Green chop (t DM/ha)	Whole crop (t DM/ha)
June treatments		
Faba bean ('Ben')	5.44	18.3
Ryecorn ('Rahu')	7.41	16.5
Triticale ('Wintermax')*	8.09	14.7
Oats ('Intimidator')*	8.05	17.8
Oats ('Intimidator'*) & plantain ('Oracle'*)	9.61	15.7
Oats, Faba & plantain	8.00	17.3
Oats, triticale, ryecorn, Faba & plantain	8.29	15.0
Weedy fallow	2.70	3.3
August treatments		
Fallow then August sowing of triticale (Wintermax)*	6.32	12.4
Fallow then August sowing of barley (Sanette)	4.55	9.1

*Triticale ('Wintermax'), oats ('Intimidator') and plantain ('Oracle') were kindly provided by Plant Research (NZ) Ltd, Luisetti and Cropmark Seeds, respectively.

Careful paddock selection for winter grazing by avoiding critical source areas (vulnerable parts of the landscape with high risk of sediment loss) and establishing a catch crop as soon as possible after winter grazing, can mitigate runoff losses. Good grazing management should be carried out at all times as it will reduce nutrient and contaminant losses to streams and waterways and minimise damage to soils and paddocks. Various practices to reduce the risk of soil loss, in addition to catch crops (e.g. at the pre-grazing, grazing and post-grazing stages of wintering), are discussed in the *Groundcovers: Guidance for intensive winter grazing* document.

Further information can also be found in the Beef+LambNZ Factsheet *Winter forage crops: management during grazing*

Weed suppression can be an additional benefit of the ground cover provided by catch crops. In a 2018 Canterbury trial, catch crops listed in Table 1 were sown at the end of June 2018 and the yields were compared with fallow. Triticale and barley crops were sown early in August 2018 (Table 1). The Faba bean catch crop was significantly weedier than any of the other catch crops. Ryecorn, followed by the triticale catch crops, had the least weed pressure (Figure 5).

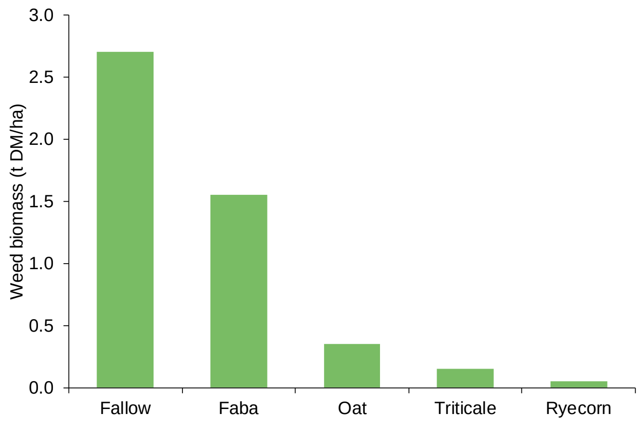


Figure 5. Weed biomass in the fallow and single species catch crops sown in June 2018, harvested for green chop silage early November 2018, Canterbury.

Organic matter returns

Catch crops have an important role to play in returning organic matter to the soil via the root carbon inputs from the increased below ground biomass (and also from any biomass above ground that is not removed or grazed). Carbon is a key determinant of soil quality because it plays a key role in most soil biological, chemical and physical processes. Soil function is improved by increasing organic matter (which is on average 58% carbon). Benefits include preservation of soil structure, improved aeration, water infiltration and water storage, and encouragement of earthworms and other soil fauna. The quantity of organic residues returned to the soil by catch crops varies depending on plant species and the length of the growing season.

What sort of catch crop is best and when is it too late?

The key attributes of catch crops when following autumn or winter grazed crops are that they:

- are cold tolerant;
- are winter active;
- have fibrous deep root systems capable of removing N throughout the soil profile.

What sort of catch crop should I use?

Cereals (e.g. oats, ryecorn, triticale, wheat or barley) make good catch crop choices after winter grazing and are proven more effective than pure ryegrass stands (e.g. Italian ryegrass, Figures 6 and 7). Cereal catch crops can be successfully established under harsh winter conditions, even if in some years sowing is not possible until late winter early spring. Including Italian or tetraploid hybrid ryegrass with a cereal, particularly in harsh, high rainfall environments (e.g., Westland, Southland), increases the probability of success and offers multiple grazings or silage cuts (Figure 8).

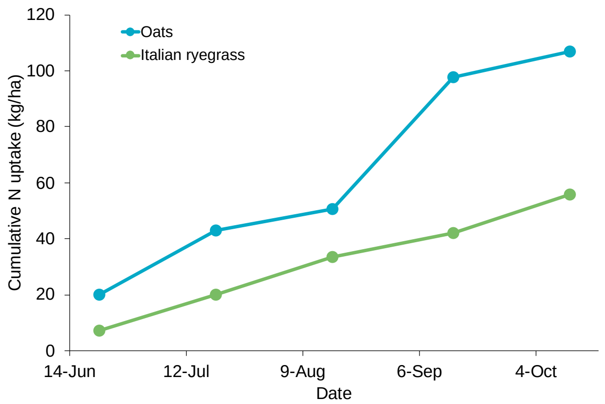


Figure 6. Crop nitrogen (N) uptake by oat or Italian ryegrass catch crops sown in early May 2017 following fodder beet grazed in April by dairy cows, Hamilton.

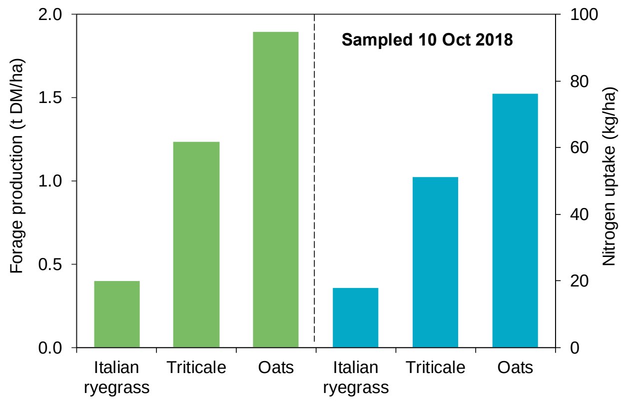


Figure 7. Mid-season crop nitrogen (N) uptake and forage production (t DM/ha) by Italian ryegrass, triticale or oat catch crops sown in mid July 2018 following kale grazed in winter by dairy cows, Canterbury. Final yields in November were 5.9, 10.1 and 12.1 t DM/ha for Italian ryegrass, triticale and oats, respectively.

Southland catch crop trial site

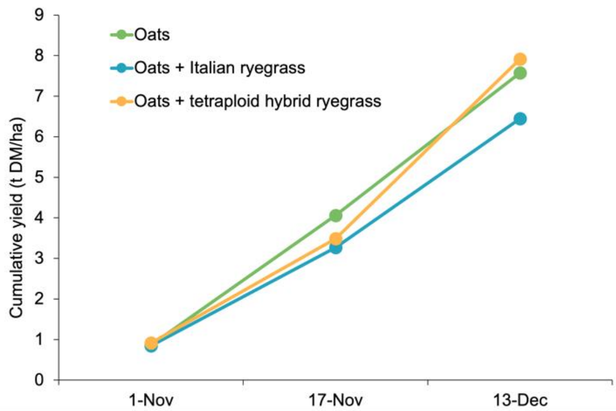


Figure 8. Cumulative forage production of oats (‘Milton’), oats + Italian ryegrass (‘Asset’) and oats + tetraploid hybrid ryegrass (‘Shogun’), sown 8 September 2022 following winter grazed swedes. Oats only were sown at 126 kg/ha, and both oats + ryegrass combinations were sown at 84 and 20 kg/ha, respectively.

In Canterbury, a wide range of cereal species (ryecorn, triticale, wheat and barley) are comparable to oats in terms of growth, N uptake and effect on soil N. This provides a degree of flexibility to select catch crops that best fit within the rotation. In colder climates, such as Southland, ryecorn and triticale can have marginally better environmental performance (N uptake) than oats. In a Southland trial in 2018, earlier growth activity of June-sown ryecorn and triticale resulted in 26–37% more N captured in the respective crops than June-sown oats (Figure 9). Such differences were not apparent when catch crops were sown in August. Weighing up the importance of early environmental gains and feed value is critical when selecting which catch crop species to use on your farm. In terms of biomass production and feed quality at green-chop silage, oats have consistently outperformed other cereals.

Another option for those wishing to renew pasture but minimise production loss is to drill a combination of both oats (seeded at approx. 80 kg/ha) and Italian or tetraploid hybrid ryegrass (seeded at approx. 20 kg/ha). This combination has been used successfully in Canterbury and was trialled in July 2019 in Southland in Lumsden and Mossburn. The oats/Italian ryegrass combination yielded only slightly less DM than the oats-only option (Figure 10) but had the added benefit of the Italian yielding further DM over the summer after the oats were harvested.

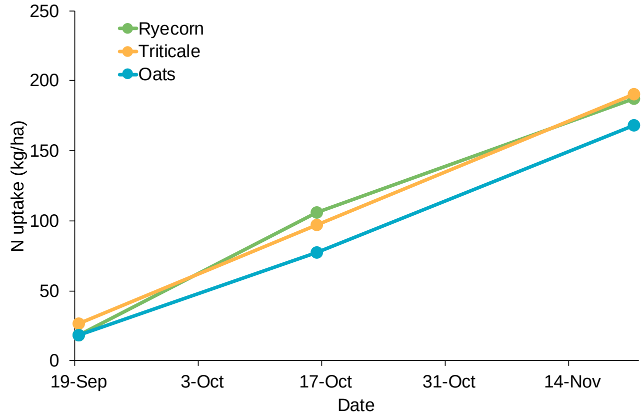


Figure 9. Cumulative nitrogen (N) uptake for catch crops sown in late June 2018 after simulated winter grazing, Southland.

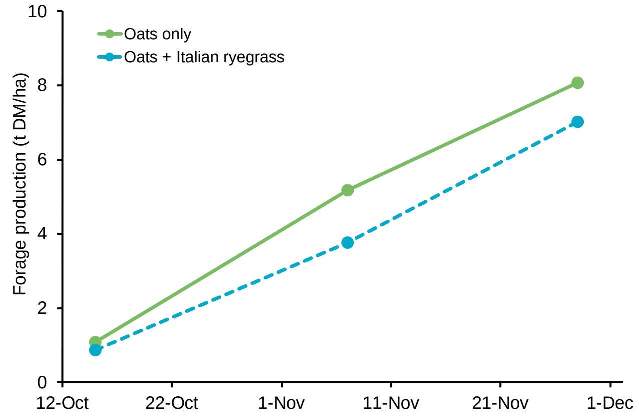


Figure 10. Comparison of dry matter (DM) yield between an oats-only (110 kg seed/ha) and an oats-Italian ryegrass mix (80 & 20 kg seed/ha, respectively) for a Southland catch crop trial, drilled 11 July 2019 after grazed fodder beet.

Yields will vary depending on season and region. Figure 11 shows yields from Waikato (2016), Canterbury (2017) and Southland (2018).

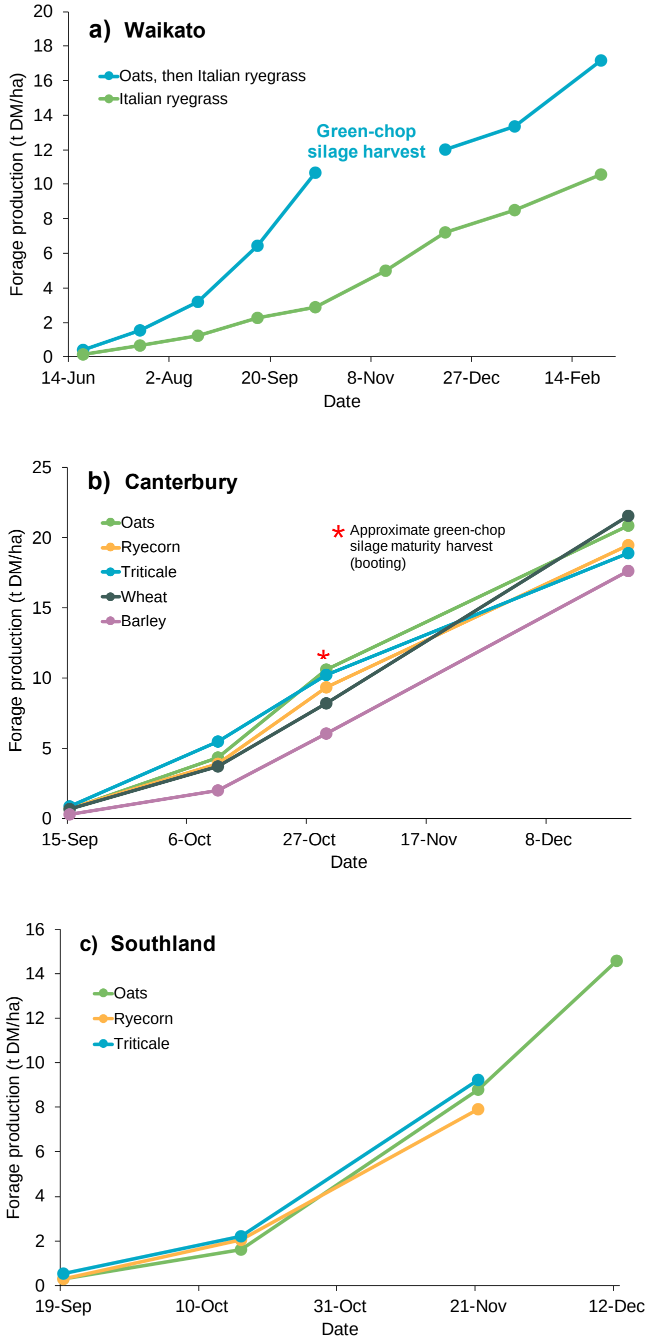


Figure 11. Cumulative forage production of a) oats and Italian ryegrass catch crops sown in early May 2017, Waikato, b) oat, ryecorn, triticale, wheat and barley catch crops sown in late June 2017, Canterbury and c) oat, ryecorn and triticale catch crops sown in June 2018, Southland.

Catch crop species trial, Waikato

Gross margins

The gross margins of catch crops will vary depending on the end-use and the individual farm system (examples given in Tables 2–7). Factors such as sowing date of the next crop or timing of feed requirements will need to be taken into consideration. The gross margin examples below provide an indication of the costs involved.

Table 2. Financial analysis of oat catch crops (standing feed) sown in July after grazing of kale by dairy cows, harvested for green chop silage in late November 2016, Canterbury.

Treatment	Yield (t DM/ha)	Revenue ($/ha)1	Costs		Margin ($/ha)
			$/ha	c/kg DM	
Cultivation	9.6	1920	719	7.5	**1201**
Direct drilled	8.4	1680	499	5.9	**1181**
Broadcast[2]	7.7	1540	577	7.5	**963**

[1]assuming $0.2/kg DM; [2]included surface grubbing and tyne crumbling.

Table 3. Financial analysis of oat catch crops (standing feed) sown in July after grazing of fodder beet by dairy cows, harvested for green chop silage in late November 2016, Canterbury.

Treatment	Yield (t DM/ha)	Revenue ($/ha)[1]	Costs		Margin ($/ha)
			$/ha	c/kg DM	
Cultivation	9.0	1800	719	8.0	**1081**
Direct drilled	6.9	1380	499	7.2	**881**
Broadcast[2]	6.8	1360	577	8.5	**783**

[1]assuming $0.2/kg DM; [2]included surface grubbing and tyne crumbling.

Table 4. Financial analysis of oat, triticale and Italian ryegrass catch crops (standing feed) sown in July 2018 after grazing of kale, harvested for green chop silage in early December 2018, Canterbury.

Treatment	Yield (t DM/ha)	Revenue ($/ha)[1]	Costs		Margin ($/ha)
			$/ha	c/kg DM	
Oats	12.1	2420	474	3.9	**1946**
Triticale	10.1	2020	588	5.5	**1462**
Italian ryegrass[2]	5.9	1180	502	8.5	**678**

[1]assuming $0.2/kg DM; [2]the Italian ryegrass is a multi-grazed crop but the gross margins presented here are for a single grazing event.

Table 5. Financial analysis of oat, triticale and ryecorn catch crops (standing feed) sown in August 2018 after grazing of fodder beet, harvested for green chop silage in early December 2018, Southland.

Treatment	Yield (t DM/ha)	Revenue ($/ha)[1]	Costs		Margin ($/ha)
			$/ha	c/kg DM	
Oats	3.7	740	560	15.1	**180**
Triticale	5.6	1120	644	11.5	**477**
Ryecorn	5.5	1100	609	11.1	**491**

[1]assuming $0.2/kg DM.

Table 6. Financial analysis of oat catch crops (standing feed) sown in August 2018 after grazing of kale or fodder beet, harvested for green chop silage in early November 2018, Canterbury.

Treatment		Yield (t DM/ha)	Revenue ($/ha)[1]	Costs		Margin ($/ha)
Previous crop	Method			$/ha	c/kg DM	
Kale	Cultivation	10.4	2080	560	5.4	**1520**
	Direct drill	9.6	1920	300	3.1	**1620**
Fodder beet	Cultivation	7.5	1500	474	6.3	**1026**
	Direct drill	7.3	1460	214	2.9	**1246**

[1]assuming $0.2/kg DM.

Table 7. Financial analysis of oat and oat + Italian ryegrass catch crops (standing feed) sown with spader-drill (July) or minimum till (September) in 2019 after grazing of kale, harvested for green chop silage in early December 2019, Southland.

Treatment			Yield (t DM/ha)	Revenue ($/ha)[1]	Costs		Margin ($/ha)
Catch crop	Method	Nitrogen fertiliser (kg N/ha)[2]			$/ha	c/kg DM	
Oats	Spader-drill	40	9.3	1860	487	5.2	**1373**
		0	8.1	1620	414	5.1	**1206**
	Minimum tillage	0	3.1	620	414	13.4	**206**
Oats + Italian	Spader-drill	40	8.6	1720	570	6.6	**1150**
		0	7.0	1400	497	7.1	**903**
	Minimum tillage	0	3.1	620	497	16.0	**123**

[1]assuming $0.2/kg DM; [2]fertiliser applied in early November

Fitting catch crops into your farm system

The choice of catch crop species will depend on the farm system, i.e. crop rotation, and the end use for that catch crop. Sufficient time must be allowed between catch crop establishment and the sowing of the subsequent spring crop to maximise the benefits of catch crops. The timing around when spring feed is required, and whether there is sufficient irrigation for the following crop, may also be important considerations. For some systems, main cereal crops such as triticale, wheat and barley could be planted early and dual-purposefully used as a catch crop as well as a main crop (e.g. whole-crop silage or grain; Figure 12).

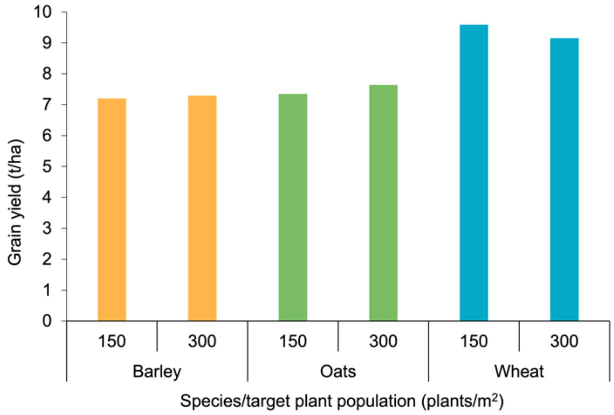


Figure 12. Grain yield of barley, oats and wheat catch crops sown on 1 September 2021 at two different target populations (150 and 300 plants/m^2) after winter-grazed fodder beet in Canterbury.

The earlier the crop is established, the greater the potential to reduce leaching

The ability of a catch crop to reduce nitrate leaching is strongly driven by the timing of its establishment after a winter grazing event (Figure 13).

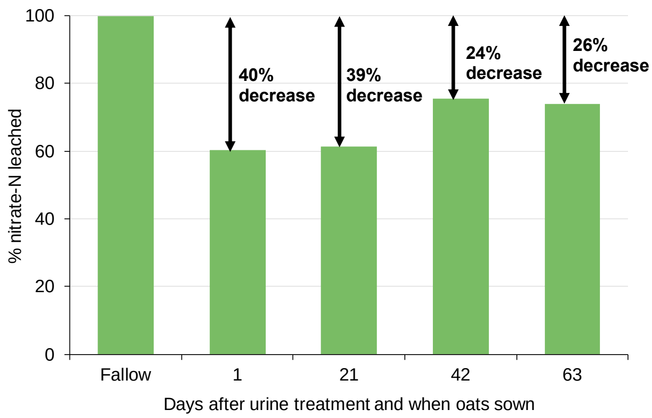


Figure 13. Percentage of nitrate-nitrogen (N) leached compared with a fallow for an oat catch crop sown 1, 21, 42 and 63 days after a winter grazing event (urine application) in Canterbury.

The high-risk drainage period is typically between June and mid-October, although this will vary by season, region and soil type. After this time catch crops can be taken through to maturity for maximum yield potential (grain or forage) or terminated earlier (late October) through grazing or incorporation as green manure crops, without compromising the likely environmental gains.

Shallow stony soils will drain earlier and faster than deeper and heavier soils. More substantial reductions in nitrate leaching occur in the mid to late part of the catch crop growth cycle, from mid-September onwards under Canterbury conditions, when a rapid increase in canopy expansion creates demand for N uptake by the crop. Figure 14 shows leaching losses over the high-risk period in Canterbury, and although the August sown oat catch crop did not reduce leaching as much as the earlier sown July catch crop, it still reduced N losses by 33%.

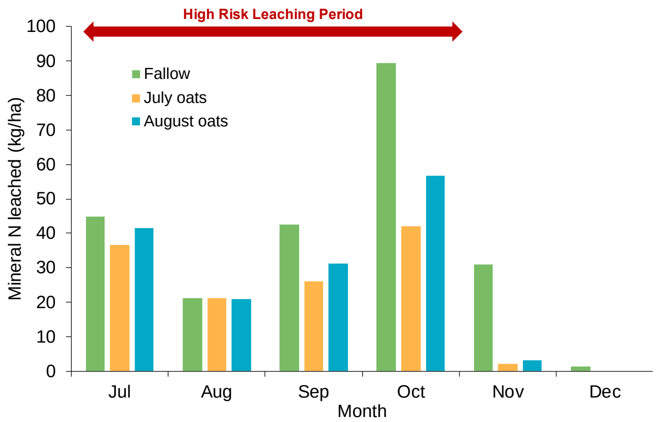


Figure 14. Monthly mineral nitrogen (N) leached in wet year from a light soil in 2017 following artificial urine deposition in July, after sowing of an oat catch crop in early July or early August, Canterbury.

The earlier the catch crop is established, the greater the potential to reduce N leaching. However, there can be significant challenges with sowing of catch crops in the middle of winter, particularly in wet and cold conditions. The weather will be an important factor affecting whether you can get onto the paddock after the grazing event to establish a catch crop. For cold tolerant crops (e.g. cereals, Italian ryegrass), soil temperatures ideally need to be at 4ºC or above. In some years, particularly on heavily pugged and/or fine-textured soils, sowing may not be possible until spring. On heavy poorly-drained soils where N leaching losses are not as prevalent, delaying sowing until spring may not actually compromise potential environmental gains. Importantly, trial data has indicated that successful catch crop emergence is only hindered by gravimetric soil moisture contents that are 40% or above for prolonged periods of time, therefore, only under particularly rare circumstances is it likely that catch crops will fail due to high moisture content.

Modelled catch crop outcomes

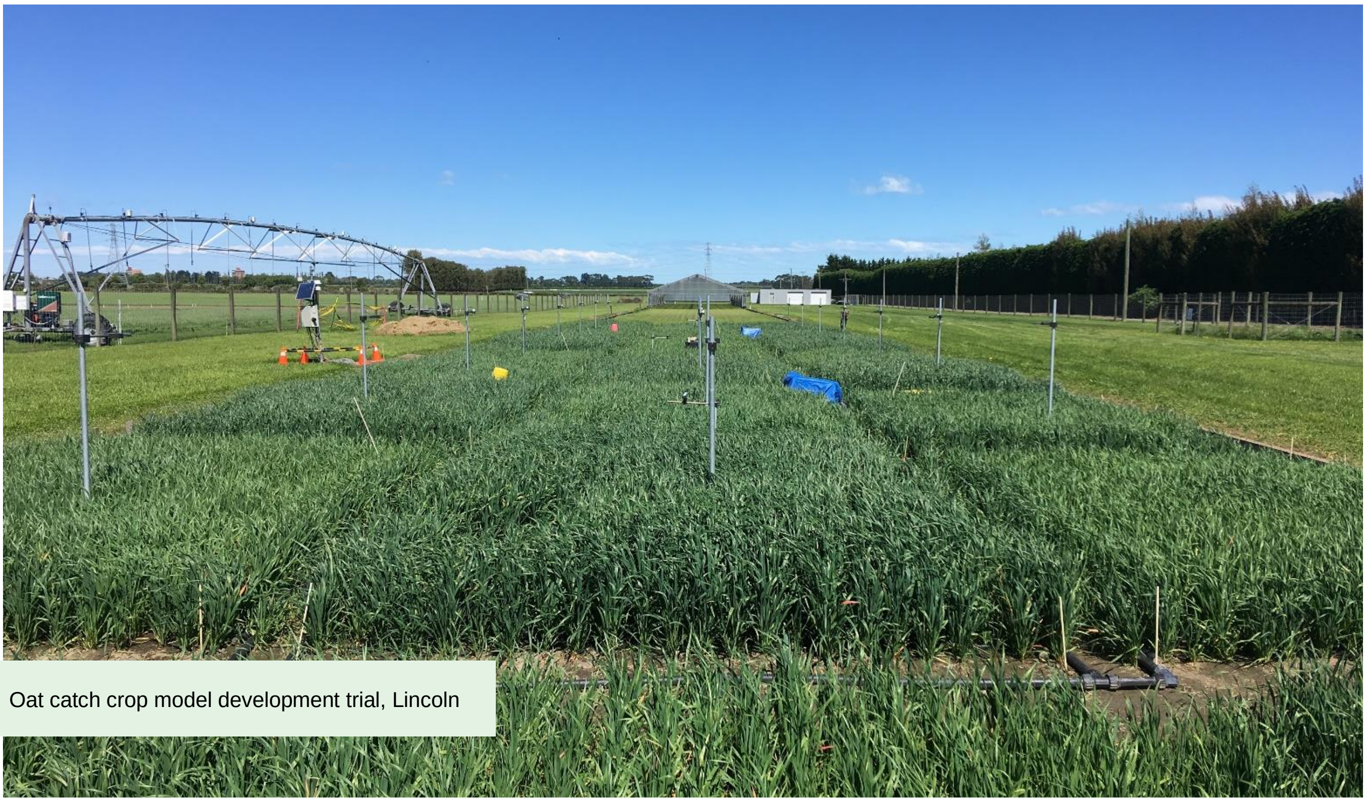
Table 8 shows simulated reduction in nitrate leaching at 80 cm, in a typical winter-spring (average of historical weather data, 1975–2000). The simulation scenarios included four different climatic regions by considering different rainfall amounts per region and four sowing dates (June, July, August and September). The table presents modelled catch crop effectiveness to reduce N leaching from residual N left in a soil with low water-holding capacity after a simulated grazing of fodder beet. The model was calibrated based on a fodder beet-oat catch crop trial. Although the methods of sowing (e.g. direct drill vs cultivation) are not considered in this modelling exercise, these and other factors also influence catch crop performance (refer to **Establishment methods** section).

Table 8. Simulated (APSIM-NextGen) paddock-scale nitrate loss reductions (%) under an oat catch crop compared with fallow conditions on a low water-holding capacity soil. Shading intensities indicate various %reduction ranges. 'Low rain' represents ≤25th percentile of long-term annual average rainfall, 'Mid rain' >25th percentile, but <75th percentile; 'High rain' ≥75th percentile.

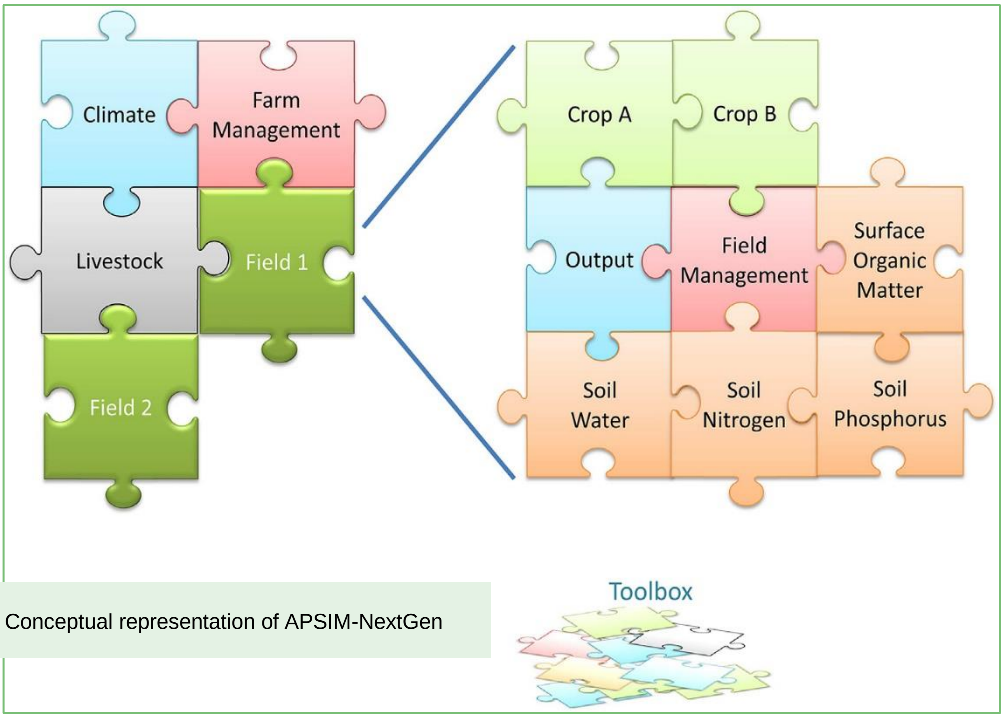
Sowing date	Southland			Canterbury			Hawkes Bay			Waikato		
	Low rain	Mid rain	High rain	Low rain	Mid rain	High rain	Low rain	Mid rain	High rain	Low rain	Mid rain	High rain
June	25%	22%	29%	65%	41%	35%	41%	20%	27%	34%	34%	23%
July	22%	17%	27%	53%	33%	30%	31%	7%	22%	28%	27%	14%
August	12%	8%	19%	41%	26%	23%	18%	4%	11%	20%	19%	7%
September	5%	0%	3%	18%	14%	10%	0%	2%	3%	12%	6%	2%

Note that estimated "relative" efficiency of catch crops (% of fallow) is 1 to 7 percent units lower for high water-holding capacity soils (data not given) because these have intrinsically lower amounts of nitrate leaching (kg/ha), particularly in southern regions (Canterbury and Southland).

Note also that the table indicates most frequent values for 25 years of current climatic conditions. However, catch crop benefits vary largely across years depending on weather conditions. For example, for Canterbury where the value was 41%, unfavourable-weather years can show values ranging from 10% to 60% depending on annual weather conditions.



Oat catch crop model development trial, Lincoln



Conceptual representation of APSIM-NextGen

How should I establish and manage a catch crop?

Key agronomic considerations

There are a number of things to consider when establishing a catch crop. A selection of these are outlined in the table below.

Important catch crop management considerations	
Timing	Catch crops should be sown as soon as practicable after forage crop grazing when average daily soil temperatures (5 cm depth) are 4°C or above, regardless of the time of year. Although they are very slow to emerge (4–5 weeks) and get going when sown in winter, the luxury uptake of N in early growth stages (high N%) means they are still having an environmental benefit. In addition, when soil temperatures begin to rise to more optimum levels in spring, the early sown crops are better positioned to more efficiently harness energy from the sun (solar radiation) and convert that into biomass, and correspondingly, N removal.
Ground conditions	Always aim to sow catch crops with as little prior cultivation as possible, while still achieving good soil-to-seed contact. Excessive cultivation could further compromise soil structure and enhance N mineralisation, which can increase the risk of nitrate leaching. Direct drilling is the preferred method of establishment, but under poor ground conditions (wet, pugged and/or compacted), some form of cultivation may be necessary.
Winter activity	Cereals such as oats, ryecorn, triticale and wheat all have good winter activity. Barley can also be used, but is slower to establish and less tolerant of wet and cold conditions. Ryecorn and triticale can have marginally better environmental performance than oats and wheat in colder climates such as Southland. Forage oats, however, is the most consistent performer in terms of yield, N uptake and quality. Sowing oats with Italian or tetraploid hybrid ryegrass is also a very good option and reduces the risk of crop failure, particularly in wetter and harsher environments on poorly drained soils (e.g. Westland, Southland).
Sowing	Target high populations (300 plants/m^2, equivalent to 110–120 kg seed/ha for oats) with cereals to minimise the time it takes for crops to reach canopy closure. Generally, aim to sow seed at about 3–4 cm depth, to ensure good soil-to-seed contact and reduce the risk of bird damage. For an oats and ryegrass combination, 80 kg oat seed/ha and 20 kg ryegrass seed/ha is generally a good rule-of-thumb. In particularly wet environments (e.g. Westland), shallower seed depth placement (<2 cm) and a rougher seedbed is likely required to prevent severe surface capping and allow seedlings to emerge.
Nutrient needs of the catch crop	Nitrogen and other nutrients are typically present in sufficient amounts to establish a catch crop after winter forage grazing. Depending on the season, paddock history, and the size of the previous fodder crop, signs of N deficiency can occur from mid-spring onwards. To ensure both crop quality and quantity targets are achieved, the crop should be monitored for these signs, with a judicious application of N fertiliser (40–50 kg N/ha) likely beneficial.
Nutrient needs of the next crop	Catch crops may deplete the soil of essential nutrients. Nitrate reduction is the objective, but other nutrients will be taken up by crops. Soil testing to determine what needs to be applied to the subsequent crop is recommended, particularly on light soils following a wet winter/spring period. For more information see Soil testing.
Weed control and paddock rolling	Suppression of weeds is important to get the maximum benefit from sowing a catch crop, particularly in the early stages of development, i.e. pre canopy closure. Using high seed rates (300 plants/m^2), and where necessary herbicides, are important to ensure faster canopy closure to suppress weeds. Depending on the method of establishment and intended use for the catch crop, rolling the paddock for large clods or stones could be necessary to ensure suitable ground conditions for harvesting. Importantly, soils should not be too wet before rolling and cereal catch crops must be at the 3-leaf stage (or no later than stem elongation) to avoid permanent damage.

Termination	Timing of harvest affects metabolisable energy and yield. Green-chop stage (booting; growth stage 45-52) is when crop quantity and quality components are well balanced. Delaying harvest beyond green-chop silage maturity results in an initial decline in ME amongst other quality components (causing a temporary reduction in feed value) which then increases again as starch is stored during grain filling. The best time for whole-crop silage harvest is when moisture content is within the range of 35–42% DM, which may occur before the completion of grain fill (growth stage 87). If ryegrass is included in the mix with a cereal, harvest delays beyond green-chop can prolong shading effects and compromise ryegrass regrowth. Some main crops (e.g., cereal grain crops) could be established earlier than they would conventionally be in spring and serve the purpose of both a catch crop and a main crop, even under the recommended high target plant populations.
Irrigation and water management	Catch crops reduce leaching by using water and reducing drainage. In dryland areas or where soil moisture restrictions may arise, water availability for the following crops will need to be considered and carefully managed.

Catch crop plant population and grain trial, Canterbury

Establishment methods

Your establishment method of choice will depend on local factors revolving around soil and climatic conditions (including the amount of crop residues remaining). There is unlikely to be a common method for all situations. More intensive cultivation may be necessary after heavy stock trampling and pugging. If cultivating is the only way to ensure the catch crop can be sown with good soil-to-seed contact, then this is the preferred option over leaving fallow. In a recent farmer survey, direct drilling of catch crops was the most common method of establishment.

Regions like Southland, where soils may be continually wet through the winter and spring, are often problematic to establish catch crops by conventional means. Trials using innovative tillage–drill combinations like the single-pass Farmax DRP 300 spader-drill ("spader") have shown that these type of specialist tillage machines can successfully drill catch crops on wet soils where more conventional tillage techniques, like minimum till or ripping/direct drilling, aren't possible at this time of year (Figure 15). Detailed measures of soil physical properties within these trials have indicated a one-off pass with this technology in the given context has no adverse effects on soil structure. In addition, on heavily pugged and/or compacted soil, research has also indicated beneficial outcomes to soil structure as a result of cultivation compared to fallow conditions.

In Canterbury, direct-drilling or light cultivation pre-drilling should be the targeted methods of establishment to minimise additional N input through mineralisation (a microbial process whereby unavailable organic N is converted into plant-available mineral N). Physical protection of soil carbon using no tillage and minimum tillage are also important to reduce structural breakdown of soil.

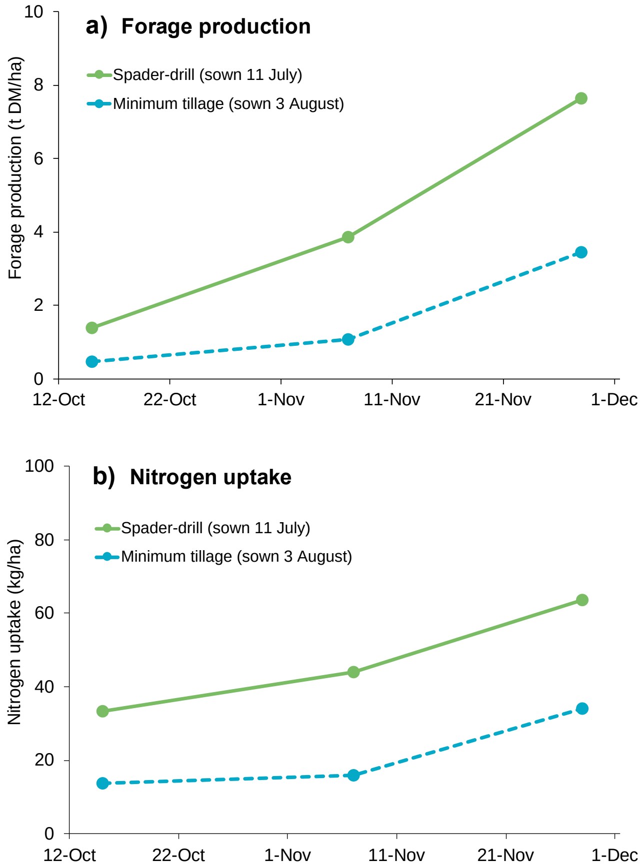


Figure 15. Forage production (t DM/ha) yield and nitrogen (N) uptake for early drilled oats (using spader-drill) vs. later-sown oats (using direct drill) after winter-grazed fodder beet, Southland, 2019.

Establishment trial

In a dry winter in Canterbury (approx. 55 mm rainfall during July and August), trial work has shown that a comparison of pre-drilling tillage and direct-drilling after grazing kale can result in equally successful oat catch crops. Cultivation after fodder beet was necessary to remediate a greater degree of soil compaction, caused by a higher stocking density than that of kale. Broadcasting oat seed after light cultivation is a very cheap option and was successful but had poorer establishment (Figure 16). As proof-of-concept for an alternative method of establishment, some oats were broadcast before fodder beet grazing; however, due to heavy trampling and severe surface capping, oats did not establish (<1% emergence). While successful catch crops can be established after all forage crops, comparisons made between grazed kale and grazed fodder beet have indicated catch crops perform marginally lower following fodder beet (Figure 16). This is mainly attributed to the greater degree of soil damage/compaction resulting from higher stocking densities during fodder beet grazing.

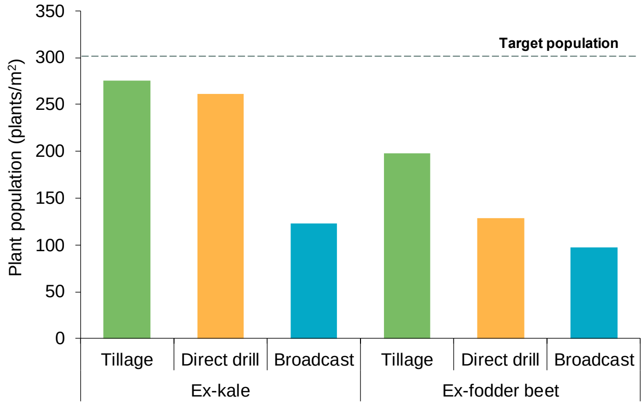


Figure 16. Plant population (plants/m^2) of oat catch crops sown in late July 2016 following grazing of either kale fodder beet comparing three establishment methods, Canterbury.

Oat catch crop establishment trial, Canterbury.

Nitrogen fertiliser management

It is well known that excessive use of N fertiliser is not just financially unwise but also results in surplus N that can be lost to the environment. Using catch crops after winter grazing and getting N application right (right source, right rate, right time and right place) can collectively reduce N leaching. Without information about how much available N is in the soil profile, incorrect amounts may be applied, so soil testing is important to maximise environmental and financial efficiencies. This is true for the forage crop, catch crop and subsequent spring crop. Alternatively, assessing the catch crop for N deficiency (yellowing of the leaves) can also indicate whether or not some N fertiliser might be required.

Importantly, if required, N fertiliser should not be applied to the catch crop until approximately mid-spring, i.e. when the crop begins to exponentially grow, and soil temperatures rise above 8°. Nitrogen applied too early, or over and above crop requirements, can compromise the environmental gains made by the catch crop.

See also information on DairyNZ's website Soil fertility for pasture

Soil N testing for crops

The nutrient inputs (urine and dung) from livestock grazing of forage crops are typically very high and often sufficient to meet the requirements for good catch crop green chop yields. Different amounts of N may remain in the soil profile following harvest of catch crops, depending on the inputs from grazing and the amounts removed in the catch crop. Consequently, we recommend soil N testing before establishing any subsequent crops to determine whether any fertiliser N additions are needed to meet crop demand. The recommended protocol for sampling and analysis of plant available N is outlined below.

Samples should be taken from 15–20 points in the paddock. Avoid sampling too close to the edge of the paddocks and areas such as gateways, water troughs or where there are obvious dung and urine patches. Mix the soil cores in a bucket or in a bag. Keep samples chilled until they are sent to the lab for testing. For ryegrass seed crops and cereals, sample to 30 cm, for pastoral crops sample to 15 cm.

The results obtained from a soil mineral N test (Min N) are typically given as mg/kg soil.

FAR's Soil Nitrogen Supply Calculator (see link below) will convert the lab result into kg/ha and calculate fertiliser requirements based on estimated crop yield. It also provides the option to include potentially mineralisable N (PMN; N that will become available over the growing season) into the fertiliser decision.

To manually convert mineral N mg/kg to kg/ha use the following equation:

Min N (kg/ha) = Min N (mg/kg) x sampling depth (cm) x bulk density (g/cm^3) x 0.1

Min N (mg/kg) and volumetric weight (g/mL) will be provided with the soil test results. Laboratory generated volumetric weights are often used in place of bulk density, however, they don't accurately represent field bulk density and can under predict soil mineral N. If you know the bulk density for your soil this would be the preferable number to use. Typical values for bulk density would be 1.1 g/cm^3 for the top 0–30 cm and 1.3 g/cm^3 for the 30–60 cm depths. A look up table for bulk density can be found in FAR's Soil Nitrogen Supply Calculator.

Once you have determined how much N is already in the soil, determine how much N your crop is likely to require, based on expected yield.

You can then calculate how much extra N you will need to apply:

Fertiliser N required = The total N requirement of the crop – soil min N

Potentially mineralisable N

Nitrogen fertiliser inputs can be further refined by accounting for the expected amount of soil organic N mineralised and made available throughout the growing season. By requesting an Anaerobic Mineralisable-N (AMN) test or Hot Water Extractable Organic N (HWEON) test, FARs N calculator can then estimate the amount of PMN and will adjust fertiliser requirements accordingly.

Quick N test

For a faster and more convenient indication of the available N status of the soil, you could consider the Quick N test. These include strips (similar to litmus strips for pH testing) that change colour depending on the nitrate concentration when placed in soil solution. Importantly, this is only a measure of nitrate, and will generally under-estimate mineral N (nitrate + ammonium). Further information can be found at the FAR link ('The confidence to cut back') given below.

Test kits are available from Laboratory Supplies (http://www.labsupply.co.nz/nitrate-test-kit).

For further information see

FAR Cropping Strategy Issue 4: Nitrogen application in wheat and barley

FAR Cropping Strategy Issue 5: Nitrogen in perennial ryegrass seed crops

FAR Research | Nitrogen: The confidence to cut back, FAR Focus 14

FAR Research | Soil nitrogen supply calculator

Soil nitrogen testing and predicting nitrogen supply · Plant & Food Research (plantandfood.com)

Links

DairyNZ Factsheet Sequence cropping kale and oats:
https://www.dairynz.co.nz/media/3360233/sequence_cropping_kale_and_oats.pdf

Beef+LambNZ Factsheet Winter forage crops: management during grazing
https://beeflambnz.com/knowledge-hub/PDF/winter-forage-crops-management-during-grazing

DairyNZ's website *Soil fertility for pasture*
https://www.dairynz.co.nz/feed/pasture-management/growing-pasture/soil-fertility-for-pasture/

FAR Cropping Strategy Issue 4 Nitrogen application in wheat and barley
https://www.dairynz.co.nz/feed/pasture-management/growing-pasture/soil-fertility-for-pasture/

FAR Cropping Strategy Issue 5 Nitrogen in perennial ryegrass seed crops
https://www.far.org.nz/assets/files/uploads/30178_FAR_cropping_strategy_issue_5_-_N_in_perennial_ryegrass.pdf

FAR's website Cereal Growth Stages Guide
https://www.far.org.nz/assets/files/uploads/35448_FAR_ute_guide_-_cereal_growth_stages_(3).pdf

Spader-drill operating in Southland