A new winter active crop to improve soil nitrogen uptake

J.R. CARADUS[1], A. RUSSELL[2], T.J. CHAPMAN[1], L. WOOD[2] and P. BOWATER[3]
[1]*Grasslanz Technology Ltd, Private Bag 11008, Palmerston North, New Zealand*
[2]*Plant Research (NZ) Ltd, 185 Kirk Road, Templeton, Christchurch, New Zealand*
[3]*Bayer NZ Ltd, 6 Centrum Lane, Rolleston, Christchurch, New Zealand*
john.caradus@grasslanz.com

Abstract
Nutrient losses due to leaching are often greatest when soils are wet and draining, mainly during winter and often after summer crops are harvested or grazed in autumn and early-winter. Cover crops such as oats have been used as a management option to reduce nitrogen leaching, but the degree of benefit is largely dependent on management for achieving high crop yields. Triticale, due largely to its ryecorn parentage, has a deep root system resulting in an excellent nutrient scavenging ability. The breeding of a new and unique triticale cultivar, T100 (marketed under the brand name of 'WinterMax'), with proven winter activity and early establishment vigour provides an improved option for nutrient 'trapping' compared with existing winter cover crops. Field trials were sown in autumn or winter after maize cropping or with differing levels of applied nitrogen, at two sites in Canterbury. The winter-active triticale removed 19, 21, 28, 35 and 45% more nitrogen from wet soils than another triticale, oats, ryecorn, wheat and annual ryegrass, respectively.

Keywords: nitrogen loss mitigation, nutrient loss, triticale, wet soils

Introduction
Nutrient losses to waterways can occur from rainwater and irrigation either by moving organic matter, sediment and nutrients from land surfaces into surface waters, or by leaching of nutrients, such as nitrogen, potassium and sulphur, through soil into groundwater (Cameron *et al*. 2013). Common mobile nutrients that move by the latter means include nitrogen, potassium and sulphur. Agricultural non-point sources account for 75% of the total nitrogen loading to New Zealand surface waters (Ministry for the Environment 2001). The principal sources of high nitrogen levels on farmland, which can lead to leaching, are urine and dung from livestock (Haynes & Williams 1993; Selbie *et al.* 2014), the application of nitrogenous fertiliser and nitrogen fixation by clovers (Monaghan *et al*. 2007; Ledgard *et al*. 2009).

Nitrogen losses due to leaching are often greatest during winter, when excess water is draining through soil. This can coincide with the period after summer crops, such as when maize, brassica or fodder beet are harvested or grazed in autumn and early-winter (Di & Cameron 2002). Quinn & Thorrold (1998) demonstrated that nitrate loadings and leaching rates, while varying through the year, are particularly high during winter when rainfall is high and plant growth is slow. The problem is further exacerbated when winter crops are strip-grazed by livestock and the paddock is left fallow until the following spring. Nutrients from the grazed crop are highly susceptible to being leached from the system with no plant growth during this period to absorb any available nutrients.

Di & Cameron (2002) described a range of management options to mitigate nitrate leaching that included reducing nitrogen application rates, synchronising nitrogen supply to plant demand, use of cover crops, better timing of ploughing pasture leys, improved stock management, precision farming and regulatory measures. Sowing of a catch crop following winter crop grazing has been shown, using lysimeters, to be an effective management strategy to reduce nitrate leaching (McLenaghen *et al.* 1996; Carey *et al*. 2016). Catch crops such as oats have been shown to reduce nitrogen leaching (Fraser *et al*. 2013; Malcolm *et al*. 2016, 2017), but the degree of benefit is largely dependent on management for achieving high catch crop yields, which focuses on sowing date and establishment method with an early sowing date being most beneficial. The challenge is to use a crop which can establish and grow during the wetter and colder winter months. Triticale, due largely to its ryecorn parentage, has a deep root system resulting in an excellent nutrient scavenging ability. However, winter activity of existing triticale cultivars has often been insufficient to impact on nutrient losses.

A new more winter-active cultivar called T100 has been bred to provide an improved option for nutrient management, compared with existing winter cover crops. The breeding programme was undertaken to select new triticale germplasm displaying excellent winter activity and early establishment vigour, to compete with winter forage oats and provide options for nutrient management through plant uptake. During the 2011 winter, an accession 011TA-347 was observed displaying these desirable characteristics. An off-type within the row stood out, having superior winter dry matter accumulation. A single head was harvested from

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this off-type and coded 011TS-429. After several years of testing in field trials, 011TS-429 was commercially released in New Zealand in 2016 under the name T100. 011TS-429 displayed an excellent level of resistance to the YR17-27 stripe rust strain. 011TS-429 has superior lodging tolerance and is classified as an early maturing variety.

The hypothesis was that this new winter-active triticale has the potential to reduce nitrogen losses from wet winter soils through improved nitrogen uptake, compared with other options currently available.

Materials and methods

Field trials

White Rock 2014

The trial design was a randomised complete block design with four replicates. The treatments were four species x two nitrogen fertiliser rates (0 and 100 kg N/ha) x two sowing dates (late autumn, mid-winter) along with a fallow control treatment. Plots (1.35 x 5 m) were established using an Ojyord drill (eight rows/plot and 15 cm spacing between rows) in a freshly grazed kale crop that yielded 10 t/ha on a Darnley soil in North Canterbury (1363 Loburn White Rock Road, Rangiora). The four species/cultivars evaluated in the trial were 'Rahu' ryecorn, 'Milton' oats, 'Tabu' Italian ryegrass and T100 triticale sown at 90, 100, 25 and 150 kg/ha, respectively.

The first sowing of the trial took place on 23rd May 2014 within a few days of the cows grazing the kale paddock. Additional nitrogen in the form of urea (100 kg/ha) was applied by hand directly after sowing as a separate treatment to ensure there was an excess of nitrogen within the soil for plant uptake. The trial site was top-worked once with a power-harrow to provide a seedbed suitable for drilling and to remove the remaining kale stalks which had been left after grazing. This, however, did not remove all of the plant debris and as a result of this and wet weather conditions that followed, plot establishment was slow and uneven in places. The trial site received no herbicide and as a result poorly established plots were overrun by weeds (predominantly Shepherd's purse) in the spring months. 'Rahu' ryecorn and T100 had the best plot establishment (around 90% ground cover) with 'Milton' oats lower (60%) as a result of many of the sown seeds rotting under the cool, wet conditions. The 'Tabu' plots resembled the fallow treatment, indicating that it would not be a suitable candidate for double-cropping at this time of the year in Canterbury. As a result, only T100 and 'Rahu' ryecorn treatments, including weeds, were harvested and compared with the fallow treatment. It is accepted as common practice to keep input costs down by not using herbicides, assuming weed levels will be kept at a low level through effective crop establishment and cold temperatures.

The second sowing was undertaken on 1st July, during a brief period of drier weather. This sowing was planted alongside the first using the same sowing and cultivation methods detailed above. The seedbed for the second sowing did not contain any kale stalks as these had been chewed off by cattle back-grazing the crop. As a result of the cleaner seed bed, plot establishment was more even in comparison with the first sowing. Like the first sowing, the second sowing received no herbicides and as a result, the 'Tabu' Italian ryegrass and 'Milton' oats plots were again overrun by Shepherd's purse and, therefore, were not included in the analysis.

Chertsey 2015

Five annual forage crops viz. T100 triticale, 'Double Take' triticale, 'Milton' oats, 'Torch' wheat and 'Hogan' annual ryegrass, were sown at the FAR Arable Site in Chertsey on 6th May 2015 following maize silage, to compare winter dry matter production from May to October. The soil type was a Templeton silt loam (Udic Haplustept, USDA soil taxonomy). A randomised complete block trial design was used with four replicates. Plots (10 x 1.5 m) were sown by New Zealand Arable using an Ojyord drill (nine rows/plot with 15 cm spacing between rows). Pre-planting germination tests showed that all species had over 90% germination. Sowing rates were adjusted to allow for differences in germination rates such that all species were sown with the aim of obtaining a population of 200 plants/m². Pre-season soil mineral nitrogen level was assessed over the whole trial area for the top 0-60 cm of soil. In August, 40 kg N/ha was applied as urea, and soil mineral nitrogen was assessed again after the final harvest on 21st October, as a bulk sample for each treatment. Dry matter yield was assessed monthly in August, September and twice in October by cutting 45 x 50 cm of crop to about a 10 cm residual height. This height is comparable to what a farmer would allow animals to graze the crop to while ensuring good recovery with the potential for a second graze. Fresh weights were recorded and samples were oven-dried at 70°C to a constant dry weight. A combined sample across the four replicates of each treatment was sent to Hill Laboratories (Christchurch) for NIR analysis to determine the forage nitrogen content. Total N harvested was calculated as %N multiplied by kg DM/ha at the final harvest. With samples bulked across replicates no statistical analysis was possible.

Statistical Analysis

Data were analysed by VSN (NZ) Limited using Genstat 64-bit Release 19.1.

Results and Discussion

Triticale is grown in the lower North Island and throughout the South Island of New Zealand for both the production of grain and forage. Triticale destined for use as a winter forage supplement is typically sown in March to early May, then grazed *in situ* in late-winter or early-spring. Depending on the rotation, the farmer may choose to leave the triticale to recover and cut it either at the boot stage (November) or as whole-crop cereal silage (January). Triticale grown for whole-crop cereal silage is usually sown in early-spring and harvested in early-summer. Triticale was consistently the highest yielding forage cereal whole-crop silage option compared with barley and wheat, yielding between 16-28 t DM/ha, depending on soil conditions, farming practices and percent dry matter at harvest (de Ruiter *et al.* 2002; Arnaudin *et al.* 2015).

White Rock 2014

T100 triticale had the highest dry matter production, within nitrogen treatments, across all three cutting dates over both sowing times (Table 1). At the final harvest of the 23rd May sowing, T100 produced 31% more dry matter at 0 kg N/ha and 35% more at 100 kg N/ha than 'Rahu' ryecorn. When sown in mid-winter (1st July) T100 produced 32% more dry matter at 0 kg N/ha and 45% more at 100 kg N/ha than 'Rahu' ryecorn. There were no significant (P>0.05) cultivar x nitrogen level interactions at any harvest date for dry matter yield.

T100 had greater winter activity than 'Rahu' ryecorn as indicated by the significantly higher (almost 1000 kg DM/ha or at least a doubling of yield irrespective of nitrogen treatment) dry matter accumulation at the first cutting when sown in late autumn (Table 1). This marked difference can be attributed to the rapid early establishment of T100 along with its erect growth type. 'Rahu' ryecorn displays a much more prostrate growth habit while developing a higher tiller base before coming away in the spring. Previous catch crop studies have shown comparable yields for oats direct-drilled into a grazed out kale paddock on 21st July and harvested on 24th November of 8.4 t DM/ha, but when harvested on the 2nd November of only 3.9 t DM/ha (Malcolm *et al.* 2017). De Ruiter *et al.* (2002) achieved single cut yields of 7.5 t DM/ha for oats and 6.9 t DM/ha for triticale. For ryecorn grown in Canterbury from 18th March to 1st September, yields of 5.25 t DM/ha have been recorded (McLenaghen *et al.* 1996), comparable to those achieved here.

Plant tissue nitrogen concentration (%) was typically highest under the fallow treatments (Table 2). The fallow treatments were predominantly overrun by Shepherds purse. The high nitrogen content for the fallow treatments may not be an accurate measure as there was no standard to calibrate the Shepherds purse against when conducting the NIR analysis of the forage sample.

T100 with 100 kg N/ha had the highest nitrogen uptake of 171 kg N/ha, over 2.5 times greater than that of the corresponding nitrogen fallow treatment of 54 kg N/ha (160 days after planting) (Table 3). T100 with 100 kg N/ha had the highest nitrogen uptake across all harvest dates irrespective of sowing date. Previous catch crop studies have shown the nitrogen uptake of oats direct-drilled into a grazed out kale paddock on 21st July and harvested on 24th November to be 114 kg N/ha, but when harvested on the 2nd November only 90 kg N/ha (Malcolm *et al.* 2017). Similarly, oats sown in July and harvested on 5th November contained 48 kg N/ha when receiving no additional nitrogen fertiliser

Table 1 Mean dry matter production (kg DM/ha) of forage crops sown at White Rock, North Canterbury on either the 23rd May or 1st July 2014, directly following the strip-grazing of kale by cattle, and harvested at three dates through September October, ranging from 111 to 160 days after planting (DAP).

Treatment		Sowing – 23rd May 2014			Sowing – 1st July 2014	
N level (kg N/ha)	Crop	Harvest date			Harvest date	
		11th September 111 DAP	25th September 125 DAP	25th September 160 DAP	25th September 87 DAP	30th October 122 DAP
0	T100 Triticale	1687	2632	9682	1058	5896
	'Rahu' - rye	802	1539	7336	616	4868
	Fallow	505	671	2548	270	1908
100	T100 - Triticale	1965	3318	10678	1246	7385
	'Rahu' - Rye	973	1937	7893	726	6544
	Fallow	751	1240	2944	273	3285
$LSD_{5\%}$		329	387	1506	174	1144
Significance level		< 0.05	< 0.05	< 0.05	< 0.05	< 0.05

but up to 144 kg N/ha when fertilised at 400 kg N/ha (Malcolm *et al*. 2016). In two other studies with oats sown in autumn, nitrogen uptake reached 80 kg N/ha (Francis 1995; Carey *et al*. 2016). For ryecorn, herbage nitrogen uptake of 118 kg N/ha has been recorded (McLenaghen *et al*. 1996).

Chertsey 2015

Throughout the trial, the triticale crops produced the greatest amount of dry matter, though the oats caught up and were also high yielding in the September and October harvests (Table 4). The annual ryegrass had comparable yields in early October, but was out-performed by both oats and triticale by 21st October. Previous studies have shown that triticale can produce higher yields than wheat, barley and oats (Arnaudin *et al*. 2015).

Pre-season soil N levels to 60 cm were 57 kg/ha and with the 40 kg N/ha added the total to 60 cm was 97 kg N/ha. T100 triticale removed 19, 45, 21 and 35% more N from wet soils than another triticale ('Double Take'), annual ryegrass, oats and wheat, respectively (Table 5). T100 was the only crop where the kg/ha of N removed at harvest exceeded the total available N (mineral N + applied N) in the soil to 60 cm (Table 5). However, the mineral N remaining in the soil to 60 cm at harvest was similar for all crops (Table 5). Zyskowski *et al*. (2016) showed in a simulated triticale catch crop trial sown in May and run over the years 1971 to 2000 in the Waikato, to have mean nitrogen uptake rates of 114 to 206 kg N/ha depending on soil water holding capacity and initial mineral N load. In Canterbury, mean herbage nitrogen uptake rates of 118 and 50 kg N/ha for ryecorn and annual ryegrass, respectively, have been recorded (McLenaghen *et al.* 1996).

Concluding comment

Cover crops can be used to markedly reduce nitrogen

Table 2 Mean plant nitrogen concentration (% of dry matter) of forage crops sown at White Rock, North Canterbury on either the 23rd May or 1st July 2014, directly following the strip-grazing of kale by cattle, harvested at three dates through September October, ranging from 111 to 160 days after planting (DAP). Samples were bulked across replicates negating statistical analysis.

Treatment		Sowing – 23rd May 2014			Sowing – 1st July 2014	
N level (kg N/ha)	Crop	Harvest date			Harvest date	
		11th September 111 DAP	25th September 125 DAP	30th October 160 DAP	25th September 87 DAP	30th October 122 DAP
0	T100 - Triticale	3.1	2.5	1.5	4.0	1.6
	'Rahu' - Rye	4.8	3.7	1.4	5.0	2.1
	Fallow	3.5	4.4	1.7	4.9	2.3
100	T100 - Triticale	3.5	3.0	1.6	4.8	2.1
	'Rahu' - Rye	5.2	4.0	1.9	5.6	2.6
	Fallow	4.8	4.9	2.0	5.8	3.3

Table 3 Plant nitrogen uptake (kg N/ha) of forage crops sown at White Rock, North Canterbury on either the 23rd May or 1st July 2014, directly following the strip-grazing of kale by cattle, and harvested at 3 dates through September October, ranging from 111 to 160 days after planting (DAP).

Treatment		Sowing – 23rd May 2014			Sowing – 1st July 2014	
N level (kg N/ha)	Crop	Harvest date			Harvest date	
		11th September 111 DAP	25th September 125 DAP	30th October 160 DAP	25th September 87 DAP	30th October 122 DAP
0	T100 - Triticale	46	66	145	42	102
	'Rahu' - Rye	28	57	103	31	102
	Fallow	10	22	36	13	40
100	T100 - Triticale	69	100	171	60	152
	'Rahu' - Rye	51	69	150	41	130
	Fallow	26	74	54	16	119

losses during winter. Zyskowski *et al.* (2016) concluded from their study that the earlier the cover crop is sown, the more biomass is grown, and the more nitrogen is taken up during the winter, and consequently, the greater the reduction in the amount of soil N susceptible to leaching. Winter-active triticale offers farmers a practical and an improved option for reducing nitrogen losses from cold, wet soils after removal of summer/autumn crops. On cultivatable soils it can be sown early (May) or later (July) into colder soils and in both cases it captures more nitrogen than other commonly used cropping options or fallow ground. The primary use for T100 is as a late-winter/early-spring single-graze forage supplement, either sown after strip-grazing of winter brassica crops, after autumn harvested beet crops, or sown after maize or any autumn harvested crops. Alternative uses are as a nutrient management tool with the potential means to mitigate nitrogen leaching after nutrient loading from autumn/winter grazed brassica crops. Typical practice is to leave fallow to spring, but T100 offers an alternative to this practice.

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DISCLAIMER

Plant Research Ltd and Grasslanz Technology Ltd jointly own T100 triticale. The Chertsey trial described here was managed by the Foundation for Arable Research (FAR).

REFERENCES

Arnaudin, M.E.; de Ruiter, J.M.; Maley, S.; Pyke, N.B. 2015. Managing whole crop cereal silage yield and profitability of autumn-sown crops. *Agronomy New Zealand 45*: 25-37.

Cameron, K.C.; Di, H.J.; Moir, J.L. 2013. Nitrogen losses from the soil/plant system: a review. *Annals of Applied Biology 162*: 145-173.

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.

De Ruiter, J.M.; Hanson, R.; Hay, A.S.; Armstrong, K.W.; Harrison-Kirk, R.D. 2002. Whole-crop cereals for grazing and silage: balancing quality and quantity. *Proceedings of the New Zealand Grassland Association 64*: 181-189.

Di, H.J.; Cameron, K.C. 2002. Nitrate leaching in temperate agroecosystems: sources, factors and mitigating strategies. *Nutrient Cycling in Agroecosystems 46*: 237-256.

Table 4 Dry matter yield (kg/ha) of triticale, ryegrass, oat and wheat varieties sown on 6th May 2015 in a trial at Chertsey, Canterbury, at four harvests from 19th August to 21st October 2015 (i.e. 105 to 168 days after planting (DAP)).

Crop	Harvest date			
	19th August 105 DAP	16th September 133 DAP	2nd October 149 DAP	21st October 168 DAP
T100 - Triticale	1164	1732	3847	7556
‘Double Take’ - Triticale	1315	1403	3336	5850
‘Hogan’ – Annual ryegrass	387	1025	2796	3838
‘Milton’ - Oats	591	1403	3221	6250
‘Torch’ - Wheat	423	854	1938	3415
Significance level	0.01	<0.001	0.01	0.001
$LSD_{5\%}$	538	321	788	1717

Table 5 Soil nitrogen and plant nitrogen uptake levels on 21st October for crops of triticale, ryegrass, oat and wheat varieties sown in a trial at Chertsey, Canterbury, on 6th May 2015.

Crop	Soil nitrogen at 0-60 cm (kg N/ha)	Nitrogen harvested (kg N/ha)
T100 - Triticale	14	100
‘Double Take’ - Triticale	11	81
‘Hogan’ – Annual ryegrass	11	55
‘Milton’ - Oats	14	79
‘Torch’ - Wheat	14	65

Francis, G.S. 1995. Management practices for minimising nitrate leaching after ploughing temporary leguminous pastures in Canterbury, New Zealand. *Journal of Contaminant Hydrology 29*: 313-327.

Fraser, P.M.; Curtin, D.; Harrison-Kirk, T.; Meenken, E.D.; Beare, M.H.; Tabley, F.; Gillespie, R.N.; Francis, G.S. 2013. Winter nitrate leaching under different tillage and winter cover crop management practices. *Soil Science Society of America Journal 77*: 1391-1401.

Haynes, R.J.; Williams, P.H. 1993. Nutrient cycling and soil fertility in the grazed pasture ecosystem. *Advances in Agronomy 49*: 119-199.

Ledgard, S.; Schils, R.; Eriksen, J.; Luo, J. 2009. Environmental impacts of grazed clover/grass pastures. *Irish Journal of Agricultural and Food Research 48*: 209-226.

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

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

McLenaghen, R.D.; Cameron, K.C.; Lampkin, N.H.; Daly, M.L.; Deo, B. 1996. Nitrate leaching from ploughed pasture and the effectiveness of winter catch crops in reducing leaching losses. *New Zealand Journal of Agricultural Research 39*: 413-420.

Ministry for the Environment 2001. Managing Waterways on Farms - A guide to sustainable riparian water management in rural New Zealand. ISBN 0 478 24016-3 ME number 385. https://www.mfe.govt.nz/sites/default/files/managing-waterways-jul01.pdf

Monaghan, R.M.; Hedley, M.J.; Di, H.J.; McDowell, R.W.; Cameron, K.C.; Ledgard, S.F. 2007. Nutrient management in New Zealand pastures – recent developments and future issues. *New Zealand Journal of Agricultural Research 50*: 181-201.

Quinn, J.M.; Thorrold, B.S. 1998. Hill-country stream management: Proceedings of a workshop, April 1998. *NIWA Technical Report 46*: 56.

Selbie, D.R.; Buckthought, L.E.; Shepherd, M.A. 2014. The challenge of the urine patch for managing nitrogen in grazed pasture systems. *Advances in Agronomy 129*: 229-292.

Zyskowski, R.F.: Teixeira, E.I.; Malcolm, B.J.; Johnstone, P.R.; de Ruiter, J.M. 2016. Effectiveness of winter cover crops to reduce nitrogen leaching losses in cropping systems in Waikato, New Zealand. *Agronomy New Zealand 46*: 109-119.