Persistence of ryegrass, tall fescue and cocksfoot following sequential annual sowings: pasture yield, composition and density in 3 establishment years under sheep grazing in Canterbury

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Abstract
A long-term pasture persistence trial, consisting of repeated annual sowings, commenced in Canterbury in 2015 and is planned to continue until 2024. Preliminary results of the first 3 years sowings are reported. Each annual sowing used the same randomised block design of eight perennial ryegrass cultivars, one tall fescue and one cocksfoot cultivar, replicated four times. Grasses were drilled into a cultivated seedbed in autumn, with white clover broadcast-sown, then rolled with a Cambridge roller. Except for one 3-week spell in spring and in autumn to accumulate herbage to measure DM yield, botanical composition, morphology and sward density, plots were continuously stocked with sheep to maintain a 3-8 cm sward height from late-August to late-May. Results from the first 12 months following each of the three annual sowings (2015, 2016 and 2017) indicate establishment year had a greater influence on DM yield, botanical composition, grass leaf and stem proportions, and basal cover than did grass species or cultivar. Accumulating data from successive annual sowings and continued monitoring of each will help identify the long-term effect and difference between establishment years, as well as grass persistence traits for inclusion in the Forage Value Index ranking of perennial ryegrass cultivars.

Keywords: long-term field trial, sown pasture establishment, *Lolium perenne, Festuca arundinacea, Dactylis glomerata*

Introduction
The 2011 Pasture Persistence Symposium (Mercer 2011) identified challenges to productive pasture longevity in New Zealand. Appropriate plant species and cultivar selection, cultivar development, and managing for greater tiller replacement mechanisms are important for improved ryegrass persistence (Clark 2011). Identifying primary driving factors (soil type, summer rainfall, plant N status, population survival mechanisms) and secondary driving factors (invertebrate pest pressure, diseases, weed ingress and high intensity grazing) which act and/or interact to determine productive sown pasture longevity are critical to understanding and therefore managing for pasture persistence (Clark 2011). Edwards & Chapman (2011) reviewed defoliation effects on morphology and population structure of perennial ryegrass and white clover pastures in the context of sown pasture yield and persistence. They concluded that if optimum pasture yield and grazing system profitability is to be achieved, conventional/established principles and practises related to plant by defoliation interactions in grazed pastures deserve re-consideration in light of recent changes in pastoral farming systems and ryegrass genotypes (for example, tetraploidy and later flowering cultivars). Thom *et al*. (2011) highlighted that long-term (5-10 years) monitoring of new pastures has received little attention, and there are limited data for assessing the effect of different establishment methods on persistence. Furthermore, Chapman *et al*. (2011) stated there are few comparisons of the ability of more recent perennial ryegrass cultivars to tolerate multiple, simultaneous resource limitations compared to older, phenotypically-different cultivars. Genotype (G) by environment (E) interactions need to be examined over more than one regionally-representative site to draw out more widely-applicable relationships between biotic and abiotic factors that drive pasture persistence (Chapman *et al*. 2015). Unravelling the complex interacting biotic and abiotic factors that drive pasture community change is important to develop the appropriate pasture management to improve persistence.

To address the above need, and to provide the DairyNZ Forage Value Index (Chapman *et al*. 2016) with persistence trait data for perennial pasture grass species, a long-term (10-15 years) pasture persistence grazing trial with sheep was initiated in 2015 on a free-draining Canterbury stony alluvial soil. This paper introduces the concept of this trial and presents preliminary data comparing the influence of establishment environmental conditions and grass species and cultivar on productive traits of the sown pasture in the first spring (grass plant population, total pasture DM yield and composition) and autumn (basal cover and tiller density) of the first growing season post-establishment.

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Methods

Experimental site preparation and design

In 2015, 2016 and 2017, a 0.3 ha pasture persistence experiment was established at the irrigated sheep unit of Lincoln University's Ashley Dene Research and Development Station, near Burnham, Selwyn District, Canterbury (43°38'34" S, 172°20'51" E; 37 m a.s.l.). Experiment areas were established in mid-autumn from sites that had been permanent sheep-grazed pasture. Seven additional 0.3 ha areas with the same experimental design and grass cultivar treatments will be established each year until 2024. The predominant soil types at the Canterbury site are shallow Balmoral and Lismore soils; stony to very stony, free-draining silty loams with low water holding capacity (80-85 mm plant available water; K. Pollock, pers. comm.). Soil moisture stress at the trial site under dryland conditions can be considerable, with plant-available water in the shallow-rooting depth soil ranging from 22 mm at 0.0-0.1 m to 5 mm at 0.4-0.5 m soil depth (Moot *et al*. 2008). Soil fertility levels ranged between pH 6.0-6.2, Olsen P 30-33 ug/L, sulphate S 7-10 mg/kg and base saturation of 67-58 %.

Ten grass cultivar treatment plots (each 12 x 4.2 m) replicated four times were established in a randomised complete block design within separate 0.3 ha paddocks in 2015, 2016 and 2017. Each of the three annual sowings had the same experimental design. Measurements were taken in mid-spring (October; approximately 6 months after sowing) and mid-autumn (April; approximately 12 months after sowing) of the establishment year of each sowing. Grass treatments include eight perennial ryegrass cultivars ranging from old to new cultivars containing one of three endophyte (*Epichloe festucae* var. *lolii*) strains (Wild-type, AR37, or AR95 - a selected analogue of Wild-type, not commercially available), one cultivar of cocksfoot ('Savvy') and one of tall fescue ('Hummer') containing endophyte MaxP® (AR584), (Table 1). Grasses were sown as untreated seed; clover seed had Superstrike™ seed coating.

The 2015 and 2016 sown pastures were established after a summer brassica break crop of 'Hunter' leafy turnip while the 2017 sown pasture was established directly after permanent pasture. The existing remnant brassica crop or pasture was sprayed out using glyphosate-based herbicide, WeedMaster 540 (a.i. 540g/L glyphosate) in late-February/early-March at 2 L/ha in 200 L of water/ha. Each paddock was then cultivated using a rotary tiller (rotovator) and Cambridge-rolled after cultivation in mid-March to form a consolidated seedbed. Seeds of the different grass species and cultivars (Table 1) were sown into the prepared seedbed using a Flexiseeder precision plot drill fitted with tine coulters (15 cm coulter spacing). White clover ('Tribute') was broadcast using a hand-spreader following drilling. Drilling occurred on 1st April 2015, 22nd March 2016 and 24th April 2017. Post-establishment control of broad-leaf weeds (including nettle, *Urtica urens*; chickweeds, *Stellaria media*, *Cerastium glomeratum;* scrambling speedwell, *Veronica persica;* and shepherd's purse, *Capsella bursa-pastoris*) was achieved in late-autumn/early-winter using the selective broad-leaf weed herbicide Pulsar (a.i. 200 g/L bentazone and 22 g/L of MCPB) applied at 5 L/ha in 300 L of water/ha.

Annual rainfall in 2015, 2016 and 2017 was 457, 525 and 668 mm, respectively (Figure 1). Rainfall for the summers of November 2015-March 2016, November 2016-March 2017 and November 2017-March 2018 was 160, 225 and 342 mm, respectively. The trial received scheduled irrigation of approximately 40 mm

Table 1 Grass species, cultivar, endophyte (% infection range 2015-2017), ploidy, heading date, seed source and sowing rate for the long-term pasture persistence trial at Ashley Dene Research and Development Station, Canterbury, New Zealand.

Grass species	Cultivar and endophyte	Ploidy	Heading date	Seed source	Sowing rate (kg seed/ha)
Perennial ryegrass	'Nui' Wild-type (83-51%)	Diploid	Mid	AgResearch	20
Perennial ryegrass	'Ruanui' AR95 (98%)	Diploid	Mid	AgResearch	20
Perennial ryegrass	'Samson' AR37 (99-90%)	Diploid	Mid	Agricom	20
Perennial ryegrass	'Request' AR37 (93-89%)	Diploid	Mid	Agricom	20
Perennial ryegrass	'Alto' AR37 (93%)	Diploid	Late	Agriseeds	20
Perennial ryegrass	'Prospect' AR37 (90-92%)	Diploid	Late	Agricom	20
Perennial ryegrass	'Halo' AR37 (90-94%)	Tetraploid	Late	Agricom	28
Perennial ryegrass	'Base' AR37 (88-93%)	Tetraploid	Late	PGGW Seeds	28
Tall fescue	'Hummer' MaxP (100-97%)			Agricom	25
Cocksfoot	'Savvy'			PGGW Seeds	10
White clover	'Tribute'			Agricom	4

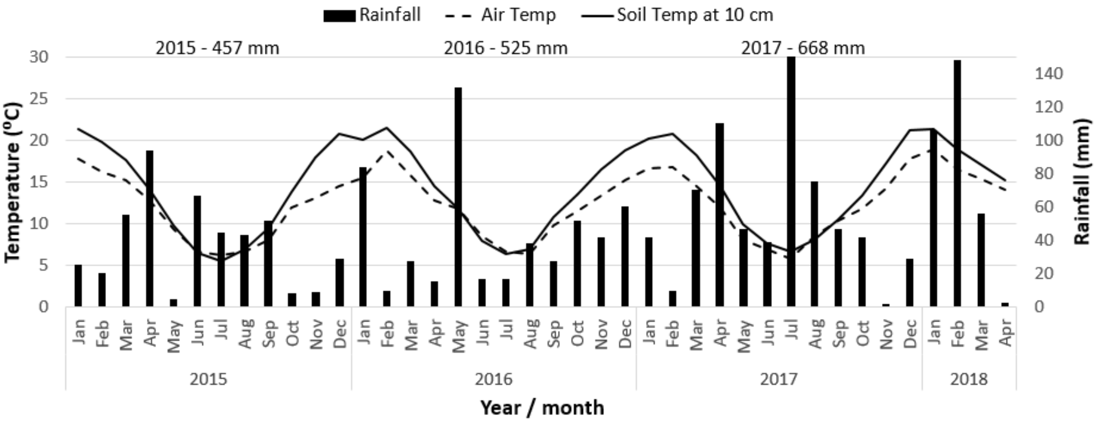

Figure 1 Annual and monthly rainfall and average soil and air temperatures at the pasture persistence experiment area at Ashley Dene Research and Development Station, Canterbury, New Zealand.

water every 12 days over summer (November to March) via a lateral irrigator system; approximately 100 mm irrigation/month, which was an adequate amount to prevent severe moisture stress over this period. Total irrigation over the 2015-2016 and 2016-2017 summers were both 500 mm. Over the 2017-2018 summer, total irrigation applied was less (200 mm) because of high rainfall in January (106 mm) and February (149 mm) of 2018.

Grazing and fertiliser management

Each annual sowing area was stocked as a single paddock, and within the paddock, sheep had free access across cultivars and replicate plots. Grazing started 3-4 months post-sowing in late-winter (August) each year, and plots were stocked continuously with sheep to maintain pasture sward height of 3-8 cm. Stocking rate was altered to match seasonally variable pasture growth rates. Pasture was grazed harder, to a 3-4 cm residual sward height, before spelling from grazing on October 1st for 3 weeks before spring sampling. Similarly, pasture areas were grazed hard again in mid-autumn before spelling on April 1st for 3 weeks regrowth for autumn basal cover and tiller density sampling. Grazing resumed after spring and autumn samplings were complete. Mechanical topping was carried out at certain times in late spring to control early seeding, and after sheep were removed on 1st October and 1st April to achieve an even sward height for 3 weeks of regrowth, before yield and botanical measurements.

Each annual sowing area received nitrogen fertiliser applied as urea (46% N) at a rate of 30 kg N/ha in early-spring (mid-September) and again in early-autumn (mid-March). Experiment areas continue to receive spring and autumn N as part of the on-going fertiliser regime. Soil tests will be conducted biennially to determine maintenance P and S requirements.

Measurements

Grass plant population was determined by counting the number of individual grass plants of the sown cultivar, along a 0.5 m section of four drill rows/plot in the first spring post-establishment. Pasture yield was measured by mowing a single strip across the plot (12 m long by × 46 cm wide, of 5.5 m^2 area) and weighing the cut herbage. A 300 g subsample was oven-dried at 65°C to determine the % DM of each sample to allow calculation of kg DM/ha. Pasture composition (grass morphological components and botanical components) was determined via 6-8 hand-snip sample cuts from each plot. Herbage collected was sorted into sown grass (leaf and stem), clover, weeds (other grass, other clover, broadleaf species) and dead matter, which were oven-dried and weighed. Basal cover was determined by placing a 25 x 25 cm quadrat divided into one hundred 2.5 x 2.5 cm cells (625 cm^2) in four random positions within the mown strip of each plot. The number of cells with more than half their area occupied by a sown grass plant were counted (after Virgona & Bowcher 2000). Tiller density of sown grass cultivars was determined by randomly placing a 15 x 15 cm quadrat at right angles to drill rows in five positions in each plot, and cutting all tillers inside the quadrat to ground level. Cut tillers from all five quadrats were combined, weighed, mixed and 150 whole tillers counted (loose leaves and daughter tillers enclosed within the parent tiller sheath were included but not counted). Non-sown grass material (other species and dead matter) were separated from sown grass material. Fresh weights for the subset of 150 counted tillers plus their loose leaves, and non-sown grass material were recorded separately, and applied to the total weight of cut herbage to calculate tiller number/m^2.

Data analysis

The influence of environmental conditions at sowing, grass cultivar and their interaction on grass establishment, pasture DM yield and composition in the first spring after sowing, and grass basal cover and tiller density 12 months after sowing, were analysed by a General ANOVA using Genstat Version 18 with sowing year and cultivar as fixed effects, and replicate blocks as random effects. The experimental unit was the mean value of the respective trait from each plot. Measurements are on-going post-establishment year, with continued intended long-term monitoring of these pastures bi-annually in spring and autumn to understand the factors driving sown pasture persistence.

Results

Environmental conditions at sowing (P<0.01) influenced grass establishment. The 2015, 2016 and 2017 sowings had an average establishment of 19.3, 18.4 and 11.3 grass plants/0.5 m row, respectively (Table 2).

Grass establishment also differed among cultivars (P<0.05). Across the three establishment years, 'Hummer' tall fescue had the lowest average plant count (13.8) and 'Samson' perennial ryegrass the highest (18), (Table 3). Establishment of 'Base' perennial ryegrass (15.8) was greater than 'Hummer' tall fescue but less than 'Samson' perennial ryegrass. Except for 'Base', all other perennial ryegrass cultivars and 'Savvy' cocksfoot had similar plant counts across establishment years, ranging between 16 - 17.9 plants/0.5 m (Table 3). There was no interaction between establishment year and cultivar on grass establishment.

In the first spring (6 months after sowing), mean total DM yield of pasture established in 2017 (2409 kg DM/ha) was 18% and 16 % greater (P<0.05) than pasture established in 2015 (2030 kg DM/ha) and 2016 (2066 kg DM/ha), respectively (Table 2). There were no total pasture yield differences among grass cultivars (Table 3) or any interaction between establishment year and grass cultivar.

Establishment conditions influenced the proportion of grass leaf (P<0.001) and grass stem (P<0.001), and the botanical proportions of white clover (P<0.001), other grasses (P<0.05), other species (P<0.001) and dead material (P<0.05) in the first spring post-sowing. The grass leaf component in 2015 (79.6 %) and 2016 sown plots (74.1%) was greater than 2017 (42.6%) sown grass plots (Table 2). There were more broadleaf (defined as 'Other species' in Table 2) species in 2017 sown pasture plots compared to 2015 and 2016 (Table 2). More grass stem was evident in 2016 sown plots (4.2%) than 2015 (2.4%), and minimal white clover was present in 2015 sown plots (1.9%; Table 2).

The proportions of grass leaf (P<0.001), grass stem (P<0.001) and white clover (P<0.05) differed among the grass species and cultivars (Table 3). 'Hummer' tall

Table 2 Influence of establishment year on grass plant establishment (plant count/0.5 m drill row), total DM yield and pasture composition in the first spring following sowing, and grass basal cover and tiller density in autumn, 12 months after sowing.

	Establishment Year					
	2015	2016	2017	SEM	P value	$LSD_{5\%}$
Plant count (plants/0.5 m row)	19.3 b	18.4 b	11.3 a	1.24	<0.01	3.98
Total yield (kg DM/ha)	2030 a	2066 a	2409 b	97.2	0.041	311.1
Pasture composition (% of DM)						
Grass leaf	79.6 b	74.1 b	42.6 a	2.26	<.001	7.24
Grass stem	2.4 b	4.2 c	0 a	0.45	<.001	1.45
White clover	1.9 a	15.1 c	10.5 b	1.12	<.001	3.59
Other grasses [1]	3.0 b	0.7 a	2.9 b	0.47	0.011	1.52
Other species [2]	8.3 a	2.7 a	37.8 b	2.95	<.001	9.43
Other clovers [3]	0.05	0	0.11	0.04	NS	-
Dead	4.4 ab	3.3 a	6 b	0.56	0.023	1.78
Basal cover (%)	24.2 b	30.5 c	13.1 a	1.2	<.001	3.89
Tiller density (number/m^2)	9958	9925	10454	1658	NS	-

[1] Annual poa *Poa annua*, soft brome *Bromus mollis*, hairgrass *Vulpia bromoides*
[2] Nettle *Urtica urens*, chickweeds *Stellaria media* and *Cerastium glomeratum*, scrambling speedwell *Veronica persica* and shepherd's purse *Capsella bursa-pastoris*
[3] Suckling clover *Trifolium dubium*, subterranean clover *T. subterraneum*

fescue had the lowest leaf proportion (49%). Amongst the perennial ryegrasses, 'Alto' and 'Ruanui' had around 64% leaf while 'Base' had the highest leaf proportion at 73%. All other ryegrass cultivars and 'Savvy' cocksfoot had leaf proportions ranging from 65-71% (Table 3). 'Nui', 'Ruanui' and 'Samson' perennial ryegrass had 6.0, 5.3 and 3.9% stem present in mid-spring. 'Request' perennial ryegrass had 3.1% and 'Hummer' tall fescue had 2.0% stem. All remaining cultivar plots had 1% or less stem present (Table 3). White clover content was greatest in 'Hummer' tall fescue plots (14.2%) and lowest in 'Request' perennial ryegrass (6.3%). All other ryegrass cultivar plots had less white clover than 'Hummer' tall fescue but not significantly more than 'Request', ranging from 7.4-11.5% (Table 3).

There was a cultivar and establishment year interaction effect on grass leaf ($P<0.05$), grass stem ($P<0.001$) and white clover ($P<0.01$) proportions in the first spring following sowing (Table 4). 'Hummer' tall fescue had relatively low leaf content consistently in all 3 sowing years, while 'Base', 'Halo', 'Prospect' and 'Nui' ryegrass had consistently high leaf content in all 3 years. Leaf content was lower overall for all cultivars in 2017 sown plots, but 'Base', 'Halo', 'Prospect' and 'Nui' still showed relatively high leaf content. 'Alto', 'Request' and 'Samson' had similarly high leaf content in 2015 and 2016 sown plots, however, leaf content in 2017 sowings of these cultivars was moderate. 'Ruanui' ryegrass sown in 2015 had high leaf content similar to 'Base', 'Halo', 'Prospect' and 'Nui', while 'Ruanui' sown in 2016 and 2017 had medium leaf content relative to other cultivars sown in the same year. 'Savvy' cocksfoot leaf content was low to moderate in 2015 and 2016 plots, but relatively high in 2017 sown plots (Table 4).

'Nui' perennial ryegrass had high stem content in 2015 and 2016 sown plots. 'Ruanui' stem content was low in 2015 sown plots and high in 2016 plots. The opposite trend was observed for 'Hummer' tall fescue, which had high stem content in 2015 sown plots but low in 2016 plots. 'Samson' and 'Request' ryegrass cultivars had relatively moderate stem content in 2015 and 2016 sown plots while 'Alto', 'Prospect', 'Halo', 'Base' and 'Savvy' cocksfoot showed minimal or no stem content in 2015 and 2016 sown plots. No grass cultivars had stem present in 2017 sown plots (Table 4).

White clover content in 2015 sown plots was low relative to 2016 and 2017 (Table 4). 'Hummer' tall fescue had the highest white clover content in 2016 sown plots (30%) followed by 'Savvy' cocksfoot (20%) which had similar white clover content to 'Base' (13%), 'Prospect' (15%), 'Samson' (14%) and 'Ruanui' (16%) ryegrass. 'Nui', 'Request', 'Alto' and 'Halo' perennial ryegrass had the lowest clover content and were similar in clover content to 'Base', 'Prospect', 'Samson'' and 'Ruanui' plots (Table 4). The range in white clover content amongst grass plots established in 2017 (7-13%) was less than 2016 sown plots (10-30%). In 2017, 'Ruanui' had the highest clover content at 18%, which was greater than 'Samson', 'Request', 'Prospect', 'Base' and 'Savvy' cocksfoot, but similar to 'Nui', 'Alto', 'Halo' and 'Hummer' tall fescue (Table 4).

Environmental conditions at establishment affected

Table 3 Influence of grass cultivar on establishment, total DM yield, basal cover, tiller density and pasture composition in the first spring following sowing (mean over 2015, 2016 and 2017 establishment years). Lower case letters separate mean component values of cultivars.

					Morphological and botanical composition (%)						
Grass cultivar	**Plant count (no./0.5 m row)**	**Total yield (kg DM/ha)**	**Basal cover (%)**	**Tiller density (number/m^2)**	**Grass leaf**	**Grass stem**	**White clover**	**Other grasses**	**Other species**	**Other clovers**	**Dead**
'Nui'	17.1 bc	2290	25.7	9290 abcd	65.3 bc	6.2 e	7.8 ab	2.9	13.3	0.0	4.5
'Ruanui'	16.8 bc	2215	22.4	12712 defg	63.7 b	5.3 de	11.5 bc	0.4	14.4	0.0	4.7
'Samson'	17.9 c	2162	20.8	9443 abcde	65.0 bc	3.9 cd	8.6 ab	2.0	15.6	0.0	5.0
'Request'	16.7 bc	2162	22.6	11107 bcdefg	67.7 bc	3.1 c	6.3 a	1.1	16.3	0.2	5.4
'Alto'	16.3 bc	2138	23.6	10480 abcdefg	64.2 b	0.1 ab	8.2 ab	1.6	21.2	0.0	4.6
'Prospect'	16.6 bc	2179	24.3	13977 g	69.3 bc	1.0 ab	8.5 ab	1.0	15.9	0.0	4.3
'Halo'	16.0 bc	2124	23.5	9048 abc	71.3 bc	0.4 ab	8.5 ab	1.3	14.7	0.0	3.8
'Base'	15.8 bc	2228	21.5	9491 abcdef	73.4 c	0.1 ab	7.4 ab	1.1	14.1	0.0	3.9
'Hummer'	13.8 a	2047	18.4	8304 ab	48.7 a	2.0 bc	14.2 c	6.8	23.8	0.3	4.3
'Savvy'	16.3 bc	2139	23.2	7232 a	67.3 bc	0.0 a	10.3 ab	4.0	13.2	0.0	5.1
SEM	1.71	61.6	2.0	1261.1	3.00	0.70	1.50	1.50	3.65	0.09	0.77
P value	0.03	ns	ns	0.011	<.001	<.001	0.02	NS	NS	NS	NS
$LSD_{5\%}$	2.02	-	-	3548.6	8.43	1.96	4.23	-	-	-	-

the basal cover of sown grasses in autumn 12 months after sowing (P<0.01), with 2017 sown plots having lower grass plant basal cover (13.1%) than 2016 (30.5%) and 2015 (24.2%) (Table 2). There was no difference in the mean basal cover among grass cultivars in autumn (Table 3).

Twelve months after sowing, pasture established in 2017 showed a trend of greater tiller density (10 454 tillers/m^2) than 2015 and 2016 established pastures (9958 and 9925 tillers/m^2, respectively; Table 2). Tiller density was significantly different (P<0.05) between some grass cultivars, however (Table 3). Averaged across the three establishment years, 'Savvy' cocksfoot, 'Hummer' tall fescue (<9000 tillers/m^2) and the perennial ryegrass cultivars 'Halo', 'Nui', 'Samson' and 'Base' were similar (9048 - 9491 tillers/m^2), while 'Alto', 'Request', 'Ruanui' and 'Prospect' had greater tiller density (10480 - 13977 tillers/m^2).

Discussion

The primary objective of this long-term field trial is to determine the factors that drive the persistence traits of yield, botanical composition, basal cover and tiller density of ten different perennial grass cultivars at this site, over multiple sowing years. Ongoing bi-annual monitoring (spring and autumn) of this field trial is intended. Typically, experiments investigating pasture persistence are based on a single sowing (e.g. a longitudinal study; Chapman *et al*. 2015; Lee *et al*. 2017). The extent to which the long-term influence of environmental factors at establishment affect persistence are not fully understood (management factors before establishment and in the critical early stages of a pastures life at and following sowing). The data presented in this paper suggests establishment environmental conditions may be important. Despite the absence of a summer break crop and its associated management factors for the pasture paddock established in 2017, the cultural and management practices around sowing for each paddock were repeated as much as possible. Over the first 12 months of the life of these pastures, there were significant differences among the three establishment years in sown grass plant density, total pasture yield, and the proportions of white clover and unsown weeds. Despite a lower sown grass plant density and a lower grass leaf proportion in the 2017 sowing, compared with 2015 or 2016, total pasture dry matter yield was greater because of a greater presence of weed species. Sown grass tiller density was numerically greater in 2017, with a significant difference in tiller density between some grass cultivars, owning to the inverse relationship between tiller size and tiller density

Table 4 Influence of grass cultivar and establishment year on grass morphological composition and proportion of white clover in the first spring following sowing. Lower case letters separate mean component values of cultivars within the same establishment year. Upper case letters separate mean component values of sowing year within the same cultivar.

	Establishment Year			Establishment Year			Establishment Year		
	2015	2016	2017	2015	2016	2017	2015	2016	2017
Grass Cultivar				Pasture component					
	% Grass leaf			% Grass stem			% White clover		
'Nui'	79 bcB	71 abcB	46 bcA	6 cB	13 cC	0 aA	1 aA	11 aB	11 abB
'Ruanui'	87 cC	64 abB	40 bA	2 aA	14 cB	0 aA	1 aA	16 abB	18 bB
'Samson'	80 bcB	72 abcB	43 bA	4 bcB	8 bC	0 aA	3 aA	14 abB	9 aAB
'Request'	83 bcB	78 bcB	42 bA	3 abcBC	6 bC	0 aA	1 aA	10 aB	8 aAB
'Alto'	76 abcB	85 cB	32 abA	0 aA	0 aA	0 aA	2 aA	10 aB	13 abB
'Prospect'	85 bcB	76 bcB	46 bcA	2 abA	1 aA	0 aA	3 aA	15 abB	7 aA
'Halo'	83 bcB	84 cB	47 bcA	1 abA	0 aA	0 aA	3 aA	12 aB	11 abB
'Base'	91 cB	81 cB	49 cA	0 aA	0 aA	0 aA	1 aA	13 abB	9 aB
'Hummer'	64 aB	59 aB	23 aA	5 cB	1 aA	0 aA	2 aA	30 cC	11 abB
'Savvy'	71 abA	71 abcA	60 cA	0 aA	0 aA	0 aA	3 aA	20 bB	8 aA
SEM	3.9	2.7	7.1	1.1	1.1	0	0.8	2.1	3.3
P value (Cultivar x Establishment Year)		0.041			<0.001			0.007	
$LSD_{5\%}$									
- Cultivar within sowing year		14.6			3.4			7.3	
- Sowing year within cultivar		15.2			3.46			7.6	

in grazed swards (Grant *et al*. 1983; Davies 1988; Hernandez-Garay *et al.* 1999). The proportion of white clover was low for the 2015 sowing compared with 2016 and 2017. These differences may have longer-term effects on persistence and stability of sown species yield.

With two exceptions, the differences observed between grass cultivars was proportionately smaller than the difference between establishment years. Firstly, tall fescue had the lowest grass plant density, the lowest proportion of grass and the highest proportion of white clover. Tall fescue has a slower rate of establishment (greater thermal time requirements for germination and emergence) than perennial ryegrass (Moot *et al.* 2000). Tozer *et al*. (2014) reported that tall fescue can support a higher proportion of white clover, perhaps owing to slower establishment relative to perennial ryegrass. Secondly, compared with the late-season flowering ryegrass cultivars (‘Prospect’, ‘Alto’, ‘Base’, ‘Halo’), the mid-season flowering cultivars (‘Nui’, ‘Ruanui’, ‘Samson’, ‘Request’) had greater proportions of stem and seedhead. This is likely related to the timing of the spring spelling period to accumulate herbage for measurement of yield and composition. More mid-season grass tillers would have commenced stem elongation by the late-October harvest date compared with the late-season cultivars. A November spelling from grazing and harvest may show a reversal of this difference by coinciding with flowering of the late-season cultivars (Wims *et al.* 2014). While there was no evidence for grass flowering date category to affect the proportion of white clover in the establishment year following each of the three annual sowings, other recent work (which included some of the cultivars in this study; ‘Alto’, ‘Base’ and ‘Prospect’) has shown that late-flowering cultivars can support a higher proportion of white clover than do mid-season cultivars (Chapman *et al*. 2018). In a 5-year pasture persistence study, Lee *et al*. (2018) reported no perennial ryegrass cultivar effect on total annual herbage accumulation across three New Zealand sites (Northland, Waikato, Canterbury) in any year. In three, successive sequences monitoring pasture establishment over 12 months following sowing, the environmental conditions surrounding establishment has had a greater influence on pasture yield, composition and sown grass density than did grass cultivars.

As this pasture persistence field trial is on-going, one purpose of this preliminary paper is to introduce the concept of this long-term trial and to share some of the research possibilities that it offers. With each successive 0.3 ha pasture area sown, the power to compare the performance longevity of the old and newer perennial ryegrass cultivars both temporally (over time; comparing the same cultivar at different time points since establishment) and spatially (comparing the same cultivar performance at a given time from multiple neighbouring paddock sites) grows. Having sequential sowings over multiple years allows comparison of persistence traits among grass cultivars over space and over time. Furthermore, this long-term trial has a corresponding sister-trial at Ruakura in the Waikato that was established at the same time, with the same experimental design and grass cultivars, but grazed by dairy heifers. Having two experimental sites allows some regional comparison between southern and northern New Zealand climatic conditions; northern regions are generally warmer, have higher rainfall and humidity, with greater pest and disease challenges. This resource will provide valuable insights about the individual and interacting factors/mechanisms/forces that drive the performance of perennial grass cultivars in New Zealand. The long-term grass persistence trait data set that this persistence trial will contribute to the Forage Value Index should be invaluable to farmers and plant breeders.

Conclusion

The year of establishment had a greater influence on productive pasture traits than did grass cultivar in the first growing season following each of three annual sowings. The accumulating long-term data from this trial will provide valuable insights into the effects of cultivar traits, and the variability among different sowing years on pasture persistence. Information on the factors affecting persistence of grass species and cultivars will be useful for cultivar ranking systems such as the Forage Value Index.

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