Persistence of perennial ryegrass, tall fescue and cocksfoot following sequential annual sowings: influence of species, cultivar and pasture age on inter-annual variability in yield and botanical composition

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Abstract

The persistence of sown, temperate pasture species is an important determinant of perennial pasture-grass productivity. Defining the traits that affect persistence is essential for improving pasture longevity through plant breeding and for identifying criteria that should be included in cultivar ranking indices such as the DairyNZ, Forage Value Index. Compared with a conventional longitudinal study, in which pasture from a single sowing is monitored over time, repeated annual sowings allow the effects on persistence of sowing year and the ensuing interactions between environment and age of pasture to be identified. A repeated sowings experiment was commenced at two sites: under sheep grazing in Canterbury, New Zealand and under cattle grazing in Waikato, New Zealand. At each site, eight cultivars of perennial ryegrass representing different ploidy, flowering date, and decade of cultivar release, and one cultivar each of tall fescue and cocksfoot were sown in a randomised complete block design with four replicates, in autumn each year. The longitudinal cohort (i.e., the measurements conducted over time following each annual sowing) is the experimental unit for effects of sowing year and age. This paper reports interim data from the longest available longitudinal cohort, sown in autumn 2016 at Waikato on pasture yield and botanical composition measured in spring and autumn for six successive years following sowing. Repeated measures analysis of the six years of pasture data was used to identify trends over time and inter-annual variability in the effects of cultivar and site.

Keywords: *Lolium perenne; Lolium arundinaceum; Dactylis glomerata; pasture establishment*; *ryegrass cultivar; persistence*

Introduction

Poor persistence of grazed, perennial ryegrass (*Lolium perenne*) pastures concerns many farmers in the warmer and drier northern and eastern areas of New Zealand. Unravelling the complex interacting biotic and abiotic factors that drive sown pasture community change is important for defining appropriate management to allow greater persistence of sown species.

To inform ryegrass cultivar ranking indices such as the DairyNZ, Forage Value Index (Chapman et al. 2017) with persistence trait data (e.g., DM yield, botanical composition), a long-term (planned 10 to 15 years) pasture persistence grazing trial was initiated at two contrasting sites in Canterbury and Waikato.

This paper reports trends and inter-annual variability in DM yield and botanical composition of a single longitudinal cohort (a single sowing date monitored over time) over six years following sowing in 2016. From this same experiment, interim data comparing the first year DM year yield and composition of pastures sown in three successive years at each site have been published (Maxwell et al. 2018; Cosgrove et al. 2020), and a comparison of a three-year-old, a two-year-old and a one-year-old pasture exposed to the same environmental conditions within the same, single year (Maxwell et al. 2021).

Materials and Methods

In 2016, a pasture persistence experiment was sown at two sites in New Zealand, Waikato (upper North Island, latitude 37.8º S) and Canterbury (mid South Island, 43.7º S). The Waikato site is a warm-humid climate with silt loam soils with poor natural drainage. In contrast, the Canterbury site is cool temperate with colder winters than Waikato but hotter, drier summers. Soils are stony to very stony free-draining silt loams with low water holding capacity. The mean annual rainfall at the Waikato site for the six years was 1085 mm (Range 754 - 1465, 30-year mean 1130 mm), and the mean rainfall during summer (Dec – Feb) was 205 mm (Range 51 -

480 mm, 30-year mean 240 mm). Further details of the experiment are available in Cosgrove et al. 2020, and Maxwell et al. 2021. Data are presented for the Waikato site only.

At each site, each annual sowing comprised 4 replicates of 8 cultivars of perennial ryegrass, and one cultivar each of tall fescue and cocksfoot, laid out in a randomised complete block design. In Waikato, the plots (18 m × 4.5 m) were intermittently grazed by dairy heifers, while at Lincoln the plots (12 m × 4.2 m) were continuously stocked with sheep, reflecting the regional differences in grazing systems. The grass species and cultivars were sown in autumn into a cultivated seedbed at each site, using a precision seeder, following a spring-sown brassica crop that was grazed in early autumn by cattle or sheep. Coulter spacing was 150 mm for each drill. White clover seed was broadcast-sown at 4 kg/ha immediately following drilling of the grasses, then the area was rolled.

Each ryegrass cultivar was infected with AR37 strain of endophyte (*Epichloe festucae* var *lolii*) and tall fescue (*Lolium arundinaceum*) was infected with *E. coenophiala*. The cocksfoot (*Dactylis glomerata*) cultivar was endophyte-free. Diploid and tetraploid cultivars of ryegrass were sown at 20 kg/ha and 28 kg/ha, respectively, tall fescue at 25 kg/ha and cocksfoot at 10 kg/ha, reflecting the differences among species in seed weight.

At each site, all plots, including the surrounding buffer areas, were grazed as a single unit. In Canterbury the continuously stocked plots were maintained at a sward height of 3 – 8 cm by varying stocking rate with season. In Waikato, the grazing protocol simulated a typical dairy rotation Macdonald and Penno, 1998). When herbage mass reached 2600 – 3000 kg DM/ha, plots were grazed by dairy heifers over a period of 24 – 48 h to leave a residual of 1500 – 1600 kg DM/ha.

For six years following sowing in autumn 2016, dry matter (DM) yield and botanical composition were measured once in spring and once in autumn. For the continuously stocked plots, the sheep were removed for 3 weeks from 1 October and 1 April and pasture allowed to accumulate to allow sufficient herbage for cutting. For the rotationally grazed dairy pasture the samples were harvested immediately prior to grazing in late-October (mid-spring) and in late-April (mid-autumn). To facilitate the accumulation of herbage for sampling, nitrogen (N) fertiliser was applied at 30 kg N/ha in early October and early April (SustaiN®).

To estimate DM yield, a strip 6 m × 0.46 m cut to a 5 cm stubble height was cut along the centre of each plot using a rotary lawn mower. The harvested herbage was weighed fresh, and a sub sample of a minimum 200 g fresh weight was then taken. This was dried at 80°C for 48 h in a forced-draft drying oven to determine DM%, and DM yield calculated. To determine botanical composition, an area 10 cm × 10 cm was cut to ground level at five sites within each plot using an electric sheep-shearing handpiece and composited into a single sample for each plot. This was subsequently separated into sown grass, white clover (*Trifolium repens*), unsown species and dead material and components dried at 80°C for 24 h and the proportion of each component determined on a DM basis. Measurements were restricted to these seasons to reflect pasture growth, composition, and density under, typically, the most favourable conditions for grasses, particularly ryegrasses, in spring (rising temperatures, generally adequate moisture, low prevalence of pests and disease) and under, typically, the least favourable conditions in autumn as pastures recover from stress (high temperatures and humidity, high prevalence of insect pests and diseases and low soil moisture). Annual DM production is highly correlated with these two extremes (Cosgrove 2011).

The log transformed data were analysed in R using a linear mixed effects model with date as a factor (R Core Team, 2020) using the "lme4" and "predictmeans" packages. Data presented in Figures 1 and2 are backtransformed means. The experimental unit consisted of the mean of the 10 species and cultivars, for each spring and autumn for the six years of measurement. There was a potential of 12 data points, consisting of 2 seasons × 6 years. No measurements were possible on the 6-month-old pastures in spring 2016, nor in autumn 2021 when the pastures were 5 years old. The first timepoint is autumn 2017, 1 year after sowing. For graphical presentation, seasons are separated, but plotted at a single time-point. Except for autumn 2017, each subsequent spring-autumn pair of values for each year are plotted as autumn i.e., 2017 spring/2018 autumn are plotted as autumn 2018, 2018 spring/2019 autumn are plotted as autumn 2019, etc.

Results

Dry matter yield. With the exception of DM yield in spring 2022 (when the pasture six and one-half years old), there was a general trend of increasing DM yield from 2017 to 2020 (Figure 1). There was substantial inter-annual variability in DM yield. There were no clear differences in yield between spring and autumn.

Botanical proportions of sown species. There were no trends with age of pasture apparent in the proportion of sown species (sown grass plus white clover) (Figure 2). Similarly, there were no discernible differences in proportions of sown species between spring or autumn.

Proportion of ryegrass. While there was no overall trend, the proportion of ryegrass declined in 2018 (pasture 2 years old), but increased again in 2022 (pasture six-years old). In the years between the proportion remained around 30%.

Proportion of white clover. While lower proportion than ryegrass overall, the slightly higher proportion in 2018 and slightly lower proportion in 2022, reflected the proportions of ryegrass. As for ryegrass there was no overall trend.

Discussion

In this paper, persistence is defined as the ability of a pasture to maintain the yield and proportion of sown species. Based on this definition, there were no significant trends over the six years of measurement in DM yield or the proportion of sown species. Thus, on these measures there was no indication showing of declining persistence. There were year-to-year variations, but any short-term declines were short-lived, and pastures recovered in yield or proportion of sown species.

Dry matter yield indicated an apparent greater level of year-to-year variability than proportions of sown species, either as the total sown species, or sown grass or white clover individually. Dry matter yield is affected more immediately, and to a greater extent by variability in rainfall. There was a two-fold variation in annual total rainfall, and a nine-fold variation in summer rainfall. Low rainfall has an immediate effect on growth rate of the grasses (especially the ryegrasses) and white clover. By comparison with rainfall, the magnitude of variation in temperature (e.g., the range in mean annual max air temperature was about 0.9°C (19.8°C – 20.7°C), and for summer was about 1.5°C (24.3°C – 25.8°C), about 5% and 6% variations, respectively, are slower in their effects on botanical composition which happen through death of herbage (decreasing proportion) or through initiation of new growth (an increasing proportion). Relative variation may also be influenced to some extent by the scale of variation; constrained to the range 0 – 100% for botanical proportions, whereas for DM yield there is no upper limit.

Assessing the inter-annual variability in grazed grass-legume pastures, in this case by following one sowing for six years is the first step in being able to separate out the confounding effects of year of sowing and the subsequent age of pasture when unpredictable stressors such as drought or insect herbivory impose their effects. The 2016 sowing and the measurements of this over six years to date, is just one longitudinal cohort. The intention is to accumulate multiple such longitudinal cohorts, and to monitor each for 10 years. This will accumulate the necessary matrix of data to test the hypothesis that episodic stressors, in combination with inter-annual variability, interacting with critical ages in a pasture life, can cause catastrophic pressure that manifests as poor persistence.

Conclusions

The lack of clear trends in yield or composition over time following sowing suggest that age of pasture *per se* is not the only factor in persistence of DM yield or botanical composition. The design of the experiment will, over time, allow for other contributing factors such as the environment at sowing and during establishment, and the effects of various stressors on pastures at different ages, to become apparent as data from subsequent longitudinal cohorts becomes available.

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References

Chapman, D.F., Bryant, J.R., Olayemi, M.E., Edwards, G.R., Thorrold, B.S., McMillan, W.H., Kerr, G.A., Judson, G., Cookson. T., Moorhead, A., and Norriss M. 2017. An economically based evaluation index for perennial and short-term ryegrasses in New Zealand dairy farm systems. *Grass and Forage Science 72*: 1-21.

Cosgrove G.P. 2011. Long-term trends in production and composition of ryegrass-white clover pasture intensively grazed by dairy-beef cattle. *Pasture Persistence Symposium. Grassland Research and Practice Series* 15. New Zealand Grassland Association, Dunedin, pp.53-62.

Cosgrove, G.P., Trolove M.R., Staincliffe M.R., and Tozer, K.N. 2020. Persistence of ryegrass, tall fescue and cocksfoot following sequential annual sowings: pasture yield, composition and density in three establishment years under cattle grazing in Waikato. *Journal of New Zealand Grasslands 82*: 149-159.

Macdonald, K.A. and Penno, J.W. 1998. Management decision rules to optimise milksolids production on dairy farms. *Proceedings of the New Zealand Society of Animal Production* 58: 132-135.

Maxwell, T.M.R., Edwards, G.R., and Cosgrove, G.P. 2018. Persistence of ryegrass, tall fescue and cocksfoot following sequential annual sowings: pasture yield, composition and density in three establishment years under sheep grazing in Canterbury. *Journal of New Zealand Grasslands 80*: 169-176.

Maxwell, T.M.R., Edwards, G.R., Tozer, K.N., and Cosgrove, G.P. 2021. Persistence of ryegrass, tall fescue and cocksfoot following sequential annual sowings: influence of cultivar and pasture age on yield, composition and density. In: G.B. Douglas (ed). Resilient Pastures Symposium. Grassland Research and Practice Series No. 17. New Zealand Grassland Association, Dunedin, pp 285-296.

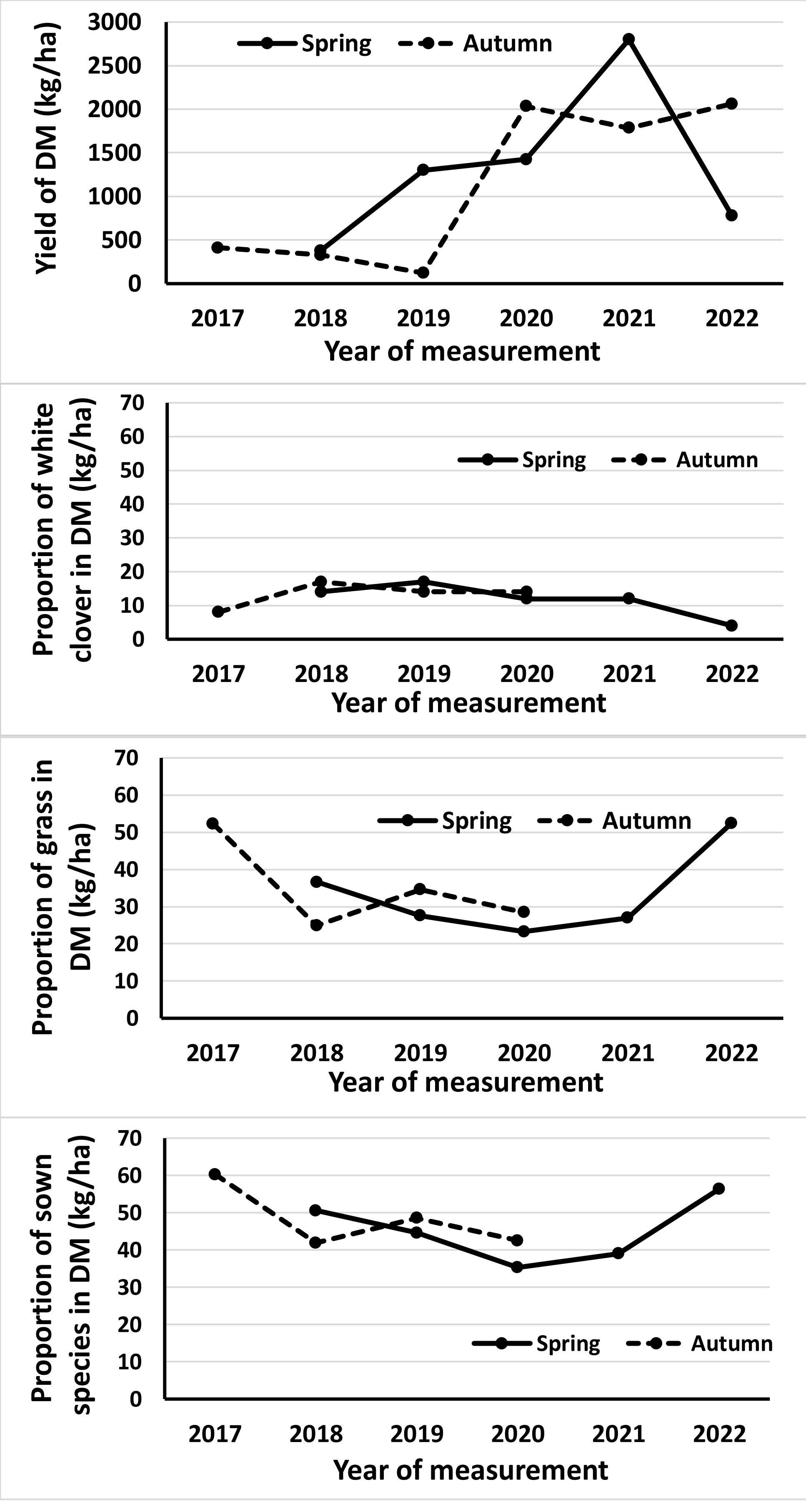
R Core Team. 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Figure 1.

Total yield of dry matter (DM) measured at a single sampling in spring and autumn of six, successive years following sowing in 2016.

Figure 2.

Proportion of white clover (Fig. 2A), grass (ryegrass, tall fescue or cocksfoot; Fig 2B) and total sown species (grass plus white clover; Fig 2C) in dry matter (DM), measured at a single sampling in spring and autumn of six, successive years following sowing in autumn 2016. There was no sample recorded in spring 2016 or autumn 2022, 12 months following the 2021 sowing.



Yield of DM (kg/ha)
3000
2500
2000
1500
1000
500
0
Spring
Autumn
2017
2018
2019
2020
2021
2022
Year of measurement
Proportion of white clover in DM (kg/ha)
70
60
50
40
30
20
10
0
Spring
Autumn
2017
2018
2019
2020
2021
2022
Year of measurement
Proportion of grass in DM (kg/ha)
70
60
50
40
30
20
10
0
Spring
Autumn
2017
2018
2019
2020
2021
2022
Year of measurement
Proportion of sown species in DM (kg/ha)
70
60
50
40
30
20
10
0
Spring
Autumn
2017
2018
2019
2020
2021
2022
Year of measurement