Changes in forage yield and botanical composition in a species diversity by harvest height by frequency experiment over 3 years in Hawke's Bay

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Abstract

There has been considerable interest in regenerative agriculture and the potential impact of diverse forage mixtures and grazing to higher residuals on pasture production and soil quality. This study evaluated the pasture production and botanical composition of two species mixtures at three defoliation heights and two defoliation frequencies. The experiment was carried out over 3 years at a summer-dry site in Hawke's Bay. The treatments were: mixtures of six cultivars of four species (ryegrass/clover) and 18 cultivars of 16 species (diverse), defoliation heights of 5, 10 and 15 cm to replicate normal, lax and very lax grazing, and defoliation frequencies of 4 and 8 weeks, over the 3 years. Total dry matter production was 23,910 kg/ha for the diverse mixture compared with 19,060 kg/ha for ryegrass/clover and decreased from 29,410 kg/ha for the 5 cm defoliation height to 21,200 kg/ha for 10 cm and 13,840 kg/ha for 15 cm, with no effect of defoliation frequency. As defoliation height increased, so did the amount of dead matter, and thus feed quality would have declined. The greater dry matter production in the diverse mixture was likely to be at least partially due to the presence of chicory and plantain.

Keywords: clover, defoliation, mixture, pasture, ryegrass

Introduction

Whilst ryegrass/clover pastures and intensive management systems have dominated the New Zealand farming landscape for many years, there has been increasing debate around the role of regenerative farming practices. Regenerative farming systems are a combination of farming principles and practices (e.g. minimum tillage, diverse pasture species, rotational grazing and reduced synthetic inputs) that regenerative practitioners claim increase diversity, enrich soils, accumulate carbon, increase soil moisture and enhance ecosystems (Terra-Genesis 2020; Grelet et al. 2021; Schreefel et al. 2020).

In a previous small-plot study, a diverse mixture of 31 species was compared with a plantain/clover mixture and a ryegrass/clover mixture at two defoliation heights (8 and 20 cm). The forages cut at 8 cm out-produced those cut at 20 cm with the plantain/clover mixture and the diverse mixture out-producing the ryegrass/clover mixture. The results suggested that the 8 cm height might have been too high for the ryegrass which is traditionally grazed lower, and suggested that a lower defoliation height should be examined (Thomson et al. 2025). They also suggested that some of the sown species in the diverse mixture (e.g. brassicas and cereals) may have compromised the performance of other species and that this could have reduced the long-term production (Thomson et al. 2025).

The aim of this study was to determine whether a diverse mixture would out-perform a ryegrass/clover mixture and whether defoliation height (5, 10 and 15 cm) and defoliation frequency (4 and 8 weeks) would impact pasture production and botanical composition.

Materials and Methods

A small-plot experiment was set up at Poukawa Research Farm in Hawke's Bay (latitude 39.746448 S, longitude 176.734201 E) on a Roseberry silt loam (Typic Orthic Melanic, USDA soil taxonomy). The experiment area was flat with a topsoil depth of around 30 cm and a soil pH of 6.3 and Olsen P of 37 µg/mL in the top 7.5 cm of the soil. The area is typically summer-dry with an average annual rainfall of around 730 mm (Mills et al. 2021).

Following a squash crop and subsequent full cultivation, a 2 × 3 × 2 factorial of two forage mixtures (ryegrass/clover and diverse), three defoliation heights (5, 10 and 15 cm) and two defoliation frequencies (4 and 8 weeks) was laid out in a randomised complete block design with four replicate blocks and 3 m × 5 m plots. The 48 plots were hand sown on 11 May 2021. Each plot was mown to 5, 10, or 15 cm using a modified mower every 4 or 8 weeks over 3 years. Cropmaster 20 (19% N, 10% P and 12% S) was applied at 200 kg/ha to each plot at sowing and in each subsequent autumn.

The diverse mixture was developed based on information from other studies on the property. It included 16 species and 18 cultivars: 1 kg lotus (*Lotus corniculatus* Cav.), 3 kg Bareno pasture brome (*Bromus valdivianus* Phil.), 2 kg timothy (*Phleum pratense* L.),

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2 kg Atom prairie grass (*Bromus willdenowii* Kunth), 2 kg Rohan perennial ryegrass (*Lolium perenne* L.), 2 kg Maxsyn perennial ryegrass, 2 kg Forge hybrid ryegrass (*Lolium* × *boucheanum* Kunth), 2 kg Matrix festulolium (× *Festulolium*), 2 kg Ruru white clover (*Trifolium repens* L.), 2 kg Apex white clover, 3 kg Morrow red clover (*T. pratense* L.), 2 kg Laser Persian clover (*T. resupinatum* L.), 2 kg Vista balansa clover (*T. michelianum* Savi), 1 kg Crimson clover (*T. incarnatum* L.), 1 kg Zulu II Arrowleaf clover (*T. vesiculosum* Savi), 0.25 kg 501 chicory (*Cichorium intybus* L.), 2 kg Captain plantain (*Plantago lanceolata* L.) and 4 kg Coolamon subterranean (sub) clover (*T. subterraneum* L.)/ha, at a total sowing rate of 36 kg/ha. The ryegrass/clover mixture was as typically sown at the research farm and included four species and six cultivars: 10 kg Rohan perennial ryegrass, 10 kg Maxsyn perennial ryegrass, 2 kg Ruru white clover, 2 kg Apex white clover, 2 kg Morrow red clover and 4 kg Coolamon sub clover/ha, at a total sowing rate of 30 kg seed/ha.

Herbage dry matter accumulation was determined by weighing the fresh herbage harvested. A 400 g subsample of the fresh forage was weighed and dried at 100°C for 48 hours to calculate the dry matter content (%). Botanical composition was measured on a pasture sample cut to ground level inside a 0.32 m × 0.32 m quadrat in October 2024 and 2025. A 200 g subsample was dissected into each sown species, weed and dead and then dried at 100°C for 48 hours and weighed. The proportion of each component on a dry matter basis was then calculated by dividing the weight of each component by the total weight of the sum of the components.

The total dry matter production and botanical composition were calculated for each plot. Data were analysed using a general linear model with mixture, defoliation height and defoliation frequency as fixed treatment effects and the interactions between the three factors evaluated. Significantly different ($P<0.05$) means were separated using Tukey's test. All analyses were carried out in Minitab version 14 software.

Results

The total dry matter production, over 3 years, was 23,910 kg/ha for the diverse mixture, compared with ($P<0.001$) 19,060 kg/ha for ryegrass/clover, and decreased ($P<0.001$) from 29,410 kg/ha for the 5 cm defoliation height to 21,200 kg/ha for 10 cm and 13,840 kg/ha for 15 cm (Table 1). An interaction between defoliation height and frequency ($P<0.01$) revealed that the decrease in dry matter production with each increase in defoliation height was lower for the 4-week (28,760, 21,890 and 15,030 kg/ha) than 8-week (29,920, 20,510 and 12,660 kg/ha) defoliation frequency.

The botanical composition differed ($P<0.05$) between the mixtures and defoliation treatments (Table 2). For the ryegrass/clover mixture defoliated at 5 cm, the main components were ryegrass and white clover, but there were increasing amounts of red clover in 2025. Generally, the red clover content appeared to increase with the decrease in defoliation frequency. By 2025, the white clover content decreased with increasing defoliation height for the 4-week defoliation frequency, and dead material increased with increasing defoliation height for both frequencies. The ryegrass content increased between 2024 and 2025 across most defoliation treatments. In the diverse mixture, any trends across the defoliation treatments were less obvious due to the greater number of species sown. However, plantain and chicory were always conspicuous and lotus, arrowleaf clover and Persian clover were never found throughout the study.

Table 1 Total dry matter production of ryegrass/clover and diverse pastures defoliated at three heights and two frequencies, over 3 years (6 April 2023 to 2 February 2026) at Poukawa Research Farm.

Defoliation Height (cm)	Defoliation Frequency (weeks)	Ryegrass/Clover	Diverse
		kg DM/ha	
5	4	26,210^{d}	31,300^{f}
10		20,290^{be}	23,480^{de}
15		12,780^{a}	17,290^{abc}
5	8	26,590^{d}	33,250^{f}
10		18,020^{bce}	22,990^{de}
15		10,480^{a}	14,830^{ac}

P Values: Mixture 0.001, Height 0.001, Frequency 0.22, Mixture × Height 0.14, Mixture × Frequency 0.17, Height × Frequency 0.004 and Mixture × Height × Frequency 0.57.
Numbers with different letters are significantly different at $P<0.05$.

Table 2 Mean botanical composition of ryegrass/clover and diverse pastures defoliated at three heights and two frequencies in October 2024 and October 2025 at Poukawa Research Farm.

		Ryegrass/Clover						Diverse													
DH	**DF**	**RG**	**WC**	**RC**	**SC**	**W**	**D**	**RG**	**F**	**T**	**PG**	**PB**	**WC**	**RC**	**CC**	**SC**	**BC**	**P**	**C**	**W**	**D**
Oct. 2024		Percentage of pasture dry matter																			
5	4	24	47	11	0	1	16	3	0	1	0	2	18	8	1	3	0	20	33	0	10
10		23	28	24	0	0	24	8	1	0	0	2	8	24	1	0	0	14	27	0	15
15		22	23	13	0	0	42	7	1	2	1	4	12	7	0	0	0	13	25	0	28
5	8	24	38	20	0	0	17	3	0	0	1	1	18	22	3	1	1	15	28	0	8
10		25	23	23	0	0	29	9	1	1	0	3	6	19	0	0	0	16	14	0	31
15		19	22	12	1	5	42	8	1	1	2	4	8	20	0	0	0	10	3	0	44
Oct. 2025																					
5	4	30	38	21	0	2	9	5	0	1	1	5	27	22	0	0	0	18	12	1	7
10		34	26	2	0	1	38	6	0	1	1	7	18	11	0	0	0	20	17	3	17
15		32	15	6	0	4	44	4	0	4	1	9	15	3	0	0	0	26	9	0	28
5	8	27	19	24	0	11	19	1	0	0	0	0	18	20	0	0	0	18	31	0	12
10		28	22	9	0	5	37	3	0	2	1	4	15	19	0	0	0	20	14	0	22
15		13	22	10	0	3	52	3	0	1	0	12	9	12	0	0	0	19	15	0	30

DH = Defoliation height (cm), DF = Defoliation frequency (weeks), RG = ryegrass, WC = white clover, RC = red clover, SC = sub clover, W = weed, D = dead, F = festulolium, T = timothy, PG = prairie grass, PB = pasture brome, CC = crimson clover, BC = balansa clover, P = plantain, C = chicory.
Lotus, arrowleaf clover and Persian clover were never found in the diverse pastures.

Discussion

Numerous researchers (e.g., Ruz-Jerez 1991; Johnson et al. 1994; Daly et al. 1996; Rollo et al. 1998; Woodward et al. 2013) have examined the effect of sowing diverse mixtures with the hypothesis that diverse swards would be more productive, or having different species in the sward (Terra-Genesis 2020; Quorum Sense 2025) would contribute to production at different times of the year. A previous small-plot study showed that higher defoliation heights reduced dry matter accumulation and that, whilst a diverse mixture produced a good level of dry matter production, only a few species contributed to the total yield (Thomson et al. 2025). Moreover, Thomson et al. (2025) found that annual species contributed to early dry matter production (e.g., cereals and brassicas made up 69% of total dry matter 8 months after sowing in the diverse mixture) then disappeared. This did give the diverse mixture an early advantage but also created the potential for areas of bare soil. Oliveira et al. (2026) found that adding cocksfoot (*Dactylis glomerata* L.) and brome to a ryegrass/clover mixture increased spring dry matter production by maintaining growth for longer. However, that study was undertaken in Manawatu, which has wetter summers than Hawke's Bay and it did not include plantain or chicory.

Thomson et al. (2025) found that, at the end of the study, only seven of the original 31 sown species were present, with seven species never seen in any of the plots and a further two species only seen after germination. Tracy and Sanderson (2004) found a similar effect with pastures dominated by perennial grasses after 3 years. In Hawke's Bay, plantain-based pastures have been shown to add value to farming systems by producing a bulk of high-quality feed in spring to enable the early sale of lambs and destocking before summer (Muir et al. 2019). Therefore, for this study, any species that did not perform in the diverse mixture study of Thomson et al. (2025) were removed, and plantain and chicory were added as potentially complimentary contributors to dry matter production and seasonality (Muir et al. 2019). In the present study, there was greater dry matter production in the diverse mixture (Table 1), with between 12% and 40% plantain and chicory in the pasture across all defoliation treatments and years (Table 2).

Thomson et al. (2025) found that increasing defoliation height reduced overall productivity, but that diverse pastures coped better than ryegrass/clover at a very lax defoliation height of 20 cm. That research suggested that even an 8 cm defoliation height was higher than would be normal for ryegrass/clover pastures to maximise dry matter production and feed quality. The present follow-up study examined how a more practical diverse mixture would compare with a ryegrass/clover mixture across a range of defoliation heights and frequencies. In this study, the diverse

mixture outperformed the ryegrass/clover mixture at all defoliation heights and frequencies (Table 1). Reducing the defoliation height increased the amount of dry matter produced and the diverse mixture maintained its superiority at the 5 cm defoliation height. Chicory and plantain were significant components in the sward even at the 5 cm defoliation height (Table 2).

Lax grazing and high post-grazing residuals are promoted as key features of regenerative agriculture (Terra Genesis 2020). However, in the current study the highest defoliation height of 15 cm resulted in more dead material in the sward (measured to ground level) than the lowest defoliation height of 5 cm (Table 2). At the higher defoliation heights, the ryegrass/clover mixture tended to have more dead material than the diverse mixture. This would reduce the edible dry matter available within the sward and have negative implications on forage quality.

Conclusions

The diverse mixture used in the present study involved species that were chosen to make a worthwhile contribution to total dry matter production, and it did outperform the ryegrass/clover mixture across all defoliation treatments. Much of the benefits seemed to be associated with the inclusion of plantain and chicory in the diverse mixture. Whether the results could be achieved under grazing is the subject of another study. Since only one third of the original sown species remained after 3 years, this diverse mixture could be further refined.

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