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Natural seedling recruitment of *Plantago lanceolata* cv. 'Ceres Tonic' in an established sward

Resiembra natural de plántulas de *Plantago lanceolata* cv. 'Ceres Tonic' en una pradera establecida

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ABSTRACT

The natural reseeding of plantain (*Plantago lanceolata* L.) in a sward mix containing plantain, chicory (*Cichorium intybus* L.), red clover (*Trifolium pratense* L.) and white clover (*Trifolium repens* L.) was monitored under conventional dairy grazing management between January and September 2015 in Manawatu, New Zealand. Measurements included numbers of seedlings emerging, and survival of tagged seedlings and their contribution to sward population densities. Seedling numbers ranged between 17-368 seedlings per m^2 and varied ($P < 0.05$) between paddocks and gradients (>15° slope versus flat). The time of seedling emergence had no effect ($P > 0.05$) on seedling survival; however seedling survival varied considerably ($P < 0.05$) between the paddocks (26% versus 76%), with higher survival following mechanical topping prior to the start of the study. Overall, at the end of the study, plantain seedlings contributed 14% of the total plantain shoots in the sward and plantain shoot density either increased or remained stable during the study period. The current study suggests that natural reseeding of plantain is significant under conventional grazing management and could be used as a management tool to maintain or increase plantain shoot density.

RESUMEN

La resiembra natural de siete venas (*Plantago lanceolata* L.) en una pradera mixta, conteniendo siete venas, chicoria, trébol rosado y trébol blanco, fue monitoreada bajo manejo de pastoreo convencional con ganado lechero entre enero y septiembre, 2015 en Manawatu, Nueva Zelanda. Las mediciones incluyeron número de plántulas emergidas, la sobrevivencia de plántulas marcadas y su contribución a la densidad de población en la pradera. El número de plántulas fluctuó entre 17 – 368 plántulas por m^2 y varió ($P<0.05$) entre las parcelas y gradientes (15° pendiente versus plano). El tiempo de emergencia de las plántulas no tuvo efecto en la sobrevivencia de plántulas, sin embargo la sobrevivencia de plántulas varió entre las parcelas (26% versus 76%), con una mayor sobrevivencia seguida de corte mecánico antes de comenzar el estudio. En general, al final del estudio, siete venas contribuyó en un 14% del total de tallos de siete venas en la pradera y la densidad de tallos de siete venas aumentó o se mantuvo estable durante el período del estudio. El presente estudio siguiere que la resiembra natural de siete venas es significante bajo un manejo de pastoreo convencional y podría ser usado como una herramienta de manejo para mantener o incrementar la densidad de tallos de siete venas.

Palabras clave: Plantago, resiembra, establecimiento, población de plantas.

INTRODUCTION

Plantain (*Plantago lanceolata* L.) is a high yielding, summer active perennial herb which can maintain high nutritive value during warm summer conditions (Lee *et al.*, 2015; Minnee *et al.*, 2013; Powell *et al.*, 2007). Plantain is increasingly being utilised in diverse pasture mixes (Nobilly *et al.*, 2013; Pembleton *et al.*, 2015; Woodward *et al.*, 2013), in mixes with chicory (*Cichorium intybus* L.), white clover (*Trifolium repens* L.) and red clover (*Trifolium pratense* L.) (Cranston *et al.*, 2015a), or as a monoculture (Lee *et al.*, 2015; Minnee *et al.*, 2013) for enhanced animal production in dairy as well as in sheep and beef systems.

Natural reseeding (seedling recruitment) has been suggested as a means by which pasture swards can either maintain persistence or be rejuvenated (East *et al.*, 1979; Hume *et al.*, 1990). The success of natural reseeding varies between pasture species (Chapman, 1987; Hume *et al.*, 1990; L'hullier and Aislabie, 1988), and has been shown to be affected by grazing management (Edwards *et al.*, 2005; Korte *et al.*, 1984; L'hullier and Aislabie, 1988), the amount of plant litter in the base of the sward (Rabotnov, 1969) and fertility (Rabotnov, 1969; Sheath and Boom, 1985). In order for seedling recruitment to be practically effective it needs to occur within the normal grazing system or require minimal loss of grazing time in the paddock.

The wild-type plantain has been described as both one of the world's most successful colonising species, and one of the world's most successful weeds (Grime *et al.*, 1988). It establishes in a wide range of habitats, regenerates by seed and some genotypes exhibit a lifespan of more than 12 years (Grime *et al.*, 1988). Natural reseeding has previously been observed in plantain (Ayala *et al.*, 2011a, b), however, the extent and outcome of reseeding within a pasture have not been quantified.

The objective of the current study was to assess the contribution of natural reseeding of plantain to sward population density in a sward mix containing; plantain, chicory, red clover and white clover.

MATERIAL AND METHODS

Site

The studies were undertaken between January and September 2015 on the Massey University Dairy 1 Farm, 5 km south of Palmerston North, New Zealand (latitude 40°S, longitude 175°E), within two existing 2 ha paddocks (paddock 30 and paddock 31). The paddocks were established in October 2013, with a sward mix containing plantain (Ceres Tonic; 6kg/ha), chicory (Puna II; 6kg/ha), red clover (Sensation; 6kg/ha) and white clover (Tribute; 4kg/ha). The botanical composition of the sward varied during the study period from between 20-50% plantain, 20-44% chicory, 5-8% red clover, 2-4% white clover and 5-25% weeds and dead material.

The soil type was a Manawatu fine sandy loam (Dystric Fluventric Eutrochrept, Hewitt 1988), with pH 5.7. Soil samples collected to a depth of 7.5 cm in September 2014 were analysed and revealed available mineral concentrations of Olsen phosphorus (P) 22 µg P/g, sulphate (S) 22.8 µg S/g, potassium 0.33 me/100g, calcium (Ca) 9.1 me/100g and magnesium 1.16 me/100g. Sulphur superphosphate 20 (8% P, 20.6% S, 18% Ca) was applied at 200kg/ha on 1 April 2015.

Climatic data collected from a New Zealand Institute of Water and Atmospheric Research climate station located approximately 500 m from the study site are presented in Table 1. Monthly rainfall was generally similar to the 10 year means throughout the study period except for January which was drier than average and April and June which were wetter than average. Minimum and maximum air temperatures were hotter in January and March than the 10 year means and colder in July and September than the 10 year means.

Grazing and pesticide management

The paddocks were strip grazed every 6-8 weeks throughout summer/autumn and again in spring, by either dairy cows or by calves (Table 2). The paddocks were not grazed during winter (June to August), as per best practice grazing management recommendations for plantain-dominant swards (Ayala *et al.*, 2011a; Cranston *et al.*, 2015a). The paddocks were grazed when the pre-grazing sward height reached a minimum of 25 cm, down to a 7 cm post-grazing residual (~1800 kgDM/ha). Prior to the start of the study period (28 December 2014), paddock 30 was mechanically topped to control reproductive stem growth. No slugs were observed during the study period; therefore no pesticide treatment was applied.

Study design

Study 1

The study consisted of two replicates (paddocks) and two treatment areas designed to vary in soil moisture content and gradient (slope and flat). The slope treatment was located on a >15° degree slope and suffered a greater moisture deficit during the summer months (average soil volumetric content of 11.3 ± 0.8 m^3 m^{-3}). The flat treatment suffered a lesser moisture deficit during the summer months (average soil volumetric content of 21.5 ± 0.8 m^3 m^{-3}). Each gradient treatment had 20 fixed plots of 0.1 m^2 (0.4 m x 0.25 m) within each paddock (20 plots × 2 gradients × 2 paddocks; making 80 plots in total). The plots were positioned every 2 m along a 40 m transect.

All plots were visually scored to assess the level of ground cover and the number of plantain seedlings per plot was counted at fortnightly intervals throughout summer/autumn and again after the first grazing in spring (6 January, 16 February, 2 March, 30 March, 14 April, 29 April and 29 September). The visual scoring was based on the percentage of the plot covered by live herbage matter (both sown and weed species) on a scale of 1-4 representing; ≤25%, 25-50%, 50-75% and 75-100% cover. The scoring was undertaken simultaneously by the same two individuals, to reduce the subjective nature of visual scoring.

Plantain plants have multiple rosettes which grow from axillary meristems (Cavers *et al.*, 1980), and therefore reliable identification of plantain plant density would require excavation. Consequently, in the current study plantain shoot (rosette) density was counted as this was considered a more consistent above-ground measure of density. Plantain shoot densities within the fixed plots were counted on 6 January, 20 May and 29 September. The plant densities of chicory and red clover within the fixed plots were also counted on these measurement dates.

Study 2

Fixed plots of 0.1 m^2 (0.4 m x 0.25 m) were established on 13 March along two transect lines within each paddock (5 plots × 2 replicate transect lines × 2 paddocks; making 20 plots in total). The position of each plot along the transect lines was selected in locations where seedlings were present on 13 March. The plots were monitored for plantain seedlings at fortnightly intervals throughout autumn and again after the first grazing in spring (13 March, 2 April, 16 April, 29 April, 25 May and 29 September).

Plantain seedlings were tagged using coloured cable wire wrapped around the base of the plant and anchored into the ground. Variations of this method were used successfully by Chapman (1987); Hume *et al.* (1990) and L'Hullier and Aislabie (1988). On each date, all new seedlings were identified and their position marked on a spatial map of the plot, following the method used by Armstrong *et al*. (2002) and Edwards *et al*. (2005). At subsequent dates, previously marked seedlings were recorded as dead or alive, with missing seedlings assigned as dead. Tags were removed from dead seedlings. Seedlings that had survived until the last sampling date (29 September), and so had survived winter and the first grazing of spring, were counted as mature plants in the final plant density count.

As per study 1, plantain shoot density and the plant density of chicory and red clover within the fixed plots were counted and recorded on 6 January, 25 May and 29 September.

Statistical analysis

All statistical analyses were performed using SAS (Statistical Analysis System, version 9.2; SAS Institute Inc., Cary, NC, US). Only significant interactions ($P < 0.05$) are presented in the results section.

Table 1. Mean monthly maximum and minimum air temperatures (°C), total monthly rainfall (mm) between January and September 2015 compared with the 10 year mean. Measurements were collected from a climate station located approximately 500 m from the study site.

Cuadro 1. Promedio mensual de temperaturas máxima y mínima (°C) y precipitación mensual total (mm) entre enero y septiembre, 2015 comparado con el promedio de 10 años. Las mediciones fueron obtenidas de una estación meteorológica ubicada aproximadamente a 500 m del sitio de estudio.

	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Max. daily air temperature (°C)	2015	25.0	23.0	23.0	19.0	16.0	13.0	11.8	13.3	14.0
	Mean (10 year)	22.5	23.3	21.7	18.8	16.2	13.6	12.9	13.4	15.4
Min. daily air temperature (°C)	2015	13.5	12.0	12.5	10.0	6.4	5.3	3.3	4.7	6.2
	Mean (10 year)	12.7	13.3	11.9	9.4	6.5	5.2	4.4	4.9	7.0
Rainfall (mm)	2015	11	56	63	152	100	165	49	91	75
	Mean (10 year)	52	55	60	84	102	100	91	84	87

Table 2. Grazing dates and stock class used to graze the sward during the study period.

Cuadro 2. Fechas de pastoreo y tipos de animales utilizados para pastorear las parcelas durante el estudio.

Paddock 30		Paddock 31	
grazing dates	**grazed with**	**grazing dates**	**grazed with**
16-22 January	32 calves	6-12 January	32 calves
27 February - 3 March	32 calves	22-27 February	32 calves
27-30 April	64 calves	23-26 April	64 calves
11 September	237 cows	14 September	237 cows

All plant density data and number of seedlings present were analysed using a mixed model and each plot was treated as a random effect. Seedling survival was binomially coded (dead = 0, alive = 1) and a logistic analysis was performed using the Genmod procedure. The mean contribution (percentage) of plantain seedlings to the total plantain shoot density was obtained after an arcsine transformation.

RESULTS

Study 1

Ground cover

The flat treatment had a greater ($P < 0.05$) level of ground cover compared to the slope treatment (average cover score of 3.0 ± 0.08 vs. 2.2 ± 0.06).

Plantain shoot density

There was a significant interaction between paddock and time for plantain shoot density ($P < 0.05$). On 6 January plantain shoot density was greater ($P < 0.05$) in paddock 31 than in paddock 30 (Figure 1). However, by 29 September 2015, plantain shoot density was greater ($P < 0.05$) in paddock 30 than in paddock 31. Furthermore, plantain shoot density increased ($P < 0.05$) between 6 January and 29 September in paddock 30, but decreased ($P < 0.05$) over the same period in paddock 31. Plantain shoot density differed between the gradients, such that the slope treatment had a greater ($P < 0.05$) shoot density than the flat (207 ± 9 vs. 101 ± 9 shoots per m^2, respectively).

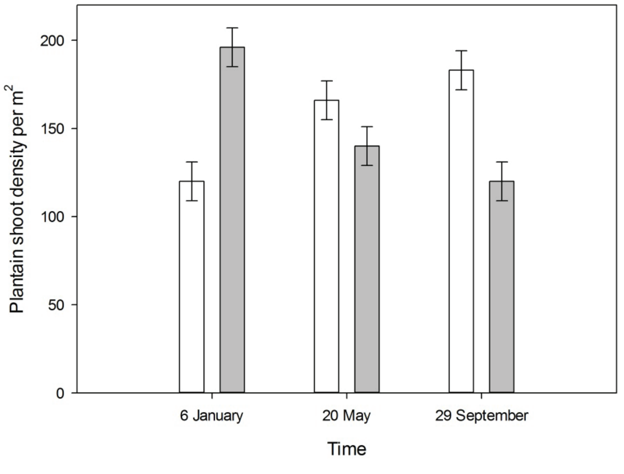

Figure 1. Study 1; Change in shoot density of plantain over time in paddock 30 (unshaded) and paddock 31 (shaded). Vertical bars represent ± standard error of mean.

Figura 1. Estudio 1; Cambio en el tiempo en la densidad de tallos de siete venas en la parcela 30 (sin sombra) y la parcela 31 (sombreada). Las barras verticales representan el error estándar de la media.

Chicory and red clover plant density

There was a significant interaction between paddock and time for chicory plant density ($P < 0.05$). On 6 January there was a greater ($P < 0.05$) chicory plant density in paddock 30 than in paddock 31, however, by 29 September there was no difference ($P > 0.05$) in the chicory density between the two paddocks (Figure 2A).

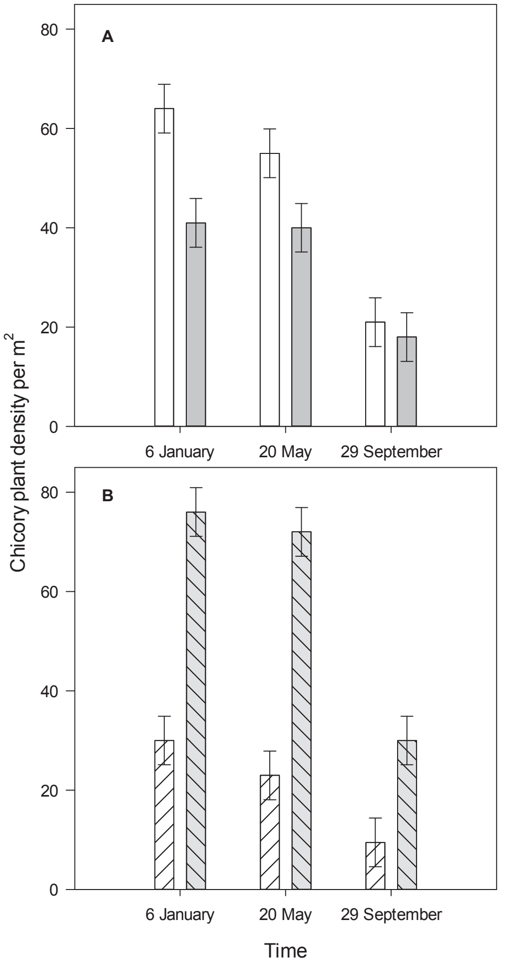

Figure 2. Study 1; Change in plant density of chicory over time in paddock 30 (unshaded) and paddock 31 (shaded) (Figure A) and between the slope (unshaded, striped) and flat (shaded, striped) treatments (Figure B). Vertical bars represent ± standard error of mean.

Figura 2. Estudio 1; Cambio en el tiempo en la densidad de plantas de achicoria en la parcela 30 (sin sombra) y la parcela 31 (sombreada) (Figura A) y entre los tratamientos de pendiente (sin sombra, líneas) y plano (sombreada, líneas) (Figura B). Las barras verticales representan el error estándar de la media.

In both paddocks, chicory plant density decreased (P < 0.05) between 6 January and 29 September.

There was also a significant interaction between gradient and time for chicory plant density, such that chicory plant density was always greater in the flat treatment than the slope treatment (P < 0.05). (Figure 2B).

There was a significant interaction between paddock and time for red clover plant density (P < 0.05; Figure 3). Red clover plant density did not differ (P > 0.05) over time in paddock 30, while in paddock 31, red clover plant density was greater (P < 0.05) on 29 September than on either 6 January and 20 May which did not differ (P > 0.05) from one another.

Time of seedling emergence

There was a significant interaction between gradient, paddock, and time of seedling emergence on the number of plantain seedlings present (P < 0.05). The number of plantain seedlings present ranged between 17-368 seedlings per m^2 over time (Figure 4). Both paddocks showed a similar pattern of seedling emergence where peak numbers of seedlings were present on 16 February and 29 September. Within paddock 30, the slope treatment had a greater (P < 0.05) number of seedlings present at each measurement date than the flat treatment, except for the 29 April when the number of seedlings present did not differ (P > 0.05) between the gradient treatments (Figure 4A). Within paddock 31, the number of seedlings present at each measurement date did not differ (P > 0.05) between the gradient treatments, except on 16 February and 29 September, when the slope treatment had a greater (P < 0.05) number of seedlings present than the flat treatment (Figure 4B).

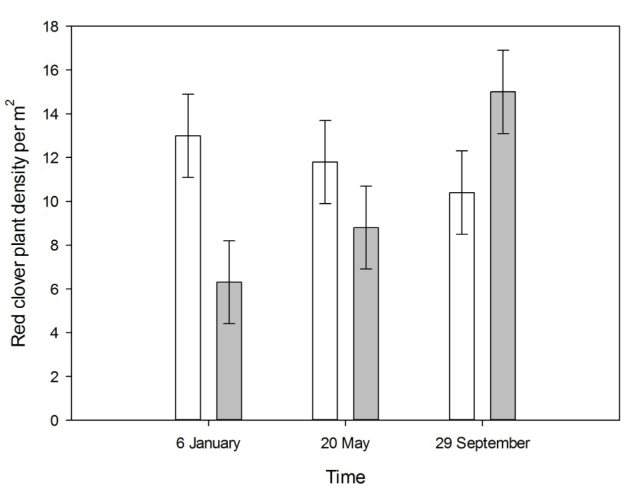

Figure 3. Study 1; Change in plant density of red clover over time in paddock 30 (unshaded) and paddock 31 (shaded). Vertical bars represent ± standard error of mean.

Figura 3. Estudio 1; Cambio en el tiempo en la densidad de plantas de trébol rosado en la parcela 30 (sin sombra) y la parcela 31 (sombreada). Las barras verticales representan el error estándar de la media.

Study 2

Plantain shoot density

There was a significant interaction between paddock and time for plantain shoot density (P < 0.05). Plantain shoot density did not differ (P > 0.05) between the two paddocks on 6 January 2015 (Figure 5). However, by

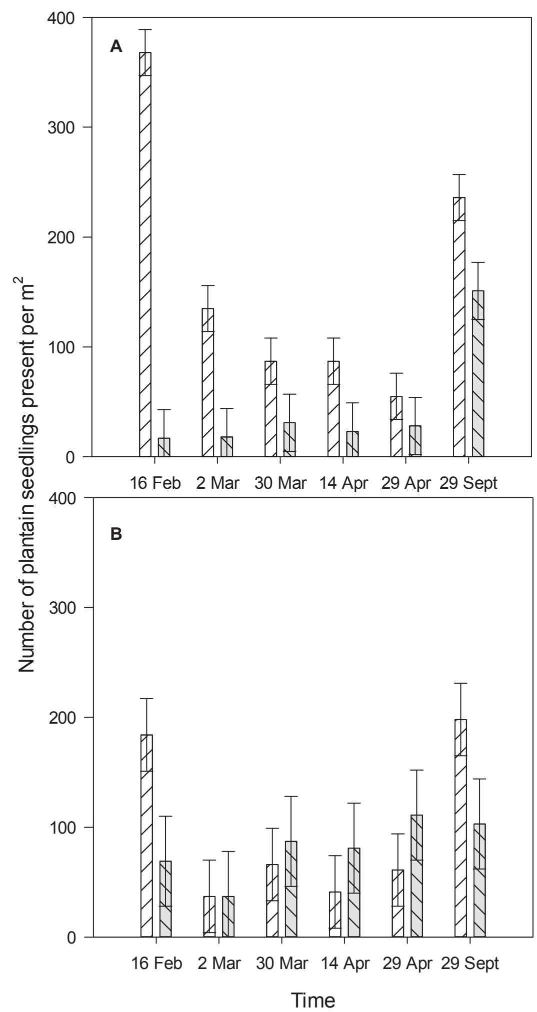

Figure 4. Study 1; Numbers of plantain seedlings per m^2 present over time in the slope treatment (unshaded, striped) compared to the flat treatment (shaded, striped) in paddock 30 (A) and paddock 31 (B). Vertical bars represent ± standard error of mean.

Figura 4. Estudio 1; Número de plántulas de siete venas por m^2 presentes en el tiempo en el tratamiento de pendiente (sin sombra, líneas) comparado con el tratamiento plano (sombreada, líneas) en la parcela 30 (A) y la parcela 31 (B). Las barras verticales representan el error estándar de la media.

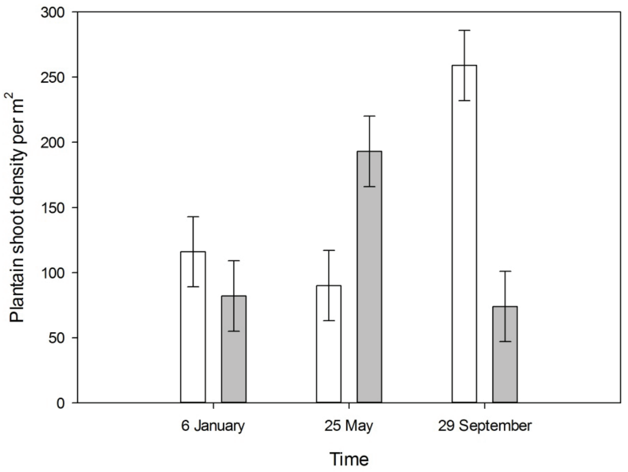

Figure 5. Study 2; Change in shoot density of plantain over time in paddock 30 (unshaded) and paddock 31 (shaded). Vertical bars represent ± standard error of mean.

Figura 5. Estudio 2; Cambio en el tiempo en la densidad de tallos de siete venas en la parcela 30 (sin sombra) y la parcela 31 (sombreada). Las barras verticales representan el error estándar de la media.

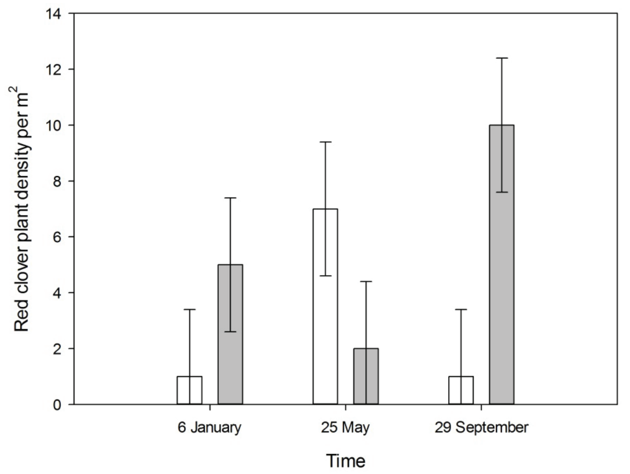

Figure 6. Study 2; Change in plant density of red clover over time in paddock 30 (unshaded) and paddock 31 (shaded). Vertical bars represent ± standard error of mean.

Figura 6. Estudio 2; Cambio en el tiempo en la densidad de plantas de trébol rosado en la parcela 30 (sin sombra) y la parcela 31 (sombreada). Las barras verticales representan el error estándar de la media.

29 September 2015, plantain shoot density was greater ($P < 0.05$) in paddock 30 than in paddock 31. Furthermore, in paddock 30, plantain shoot density was greater ($P < 0.05$) on 29 September than on 6 January.

Chicory and red clover plant density

There was no significant interaction between paddock and time for chicory plant density ($P > 0.05$). Chicory plant density did not differ ($P > 0.05$) between the two paddocks, such that average plant density was 30 ± 6 plants per m^2. Chicory plant density differed over time, such that chicory density was lower ($P < 0.05$) on 29 September than on 25 May, but neither sampling date differed ($P > 0.05$) from that on 6 January (16 ± 7 vs. 44 ± 7 vs. 30 ± 7 plants per m^2, respectively).

There was a significant interaction between paddock and time for red clover density ($P < 0.05$). In both paddocks, red clover plant density did not differ ($P > 0.05$) between 6 January and 29 September (Figure 6), but on 29 September, red clover plant density was greater ($P < 0.05$) in paddock 31 than in paddock 30.

Plantain seedling survival and contribution to the sward

Time of seedling emergence had no effect ($P > 0.05$) on plantain seedling survival (Table 3). A greater ($P < 0.05$) proportion of seedlings which emerged in paddock 30 survived compared to those which emerged in paddock 31 (Table 3). As at 29 September 2015, plantain seedlings which had emerged the previous autumn contributed a mean of 13.9 ± 13.1 % and a median of 15.7 % of total plantain shoots in the sward.

Table 3. Effect of paddock and time of seedling emergence on plantain seedling survival (Least square mean ± standard error of mean). Means within main effects with differing letters are significantly different at $P < 0.05$.

Caudro 3. Efecto de la parcela y el momento de emergencia de plántulas en la sobrevivencia de plántulas de siete venas (media de los cuadrados mínimos ± error estándar de la media). Promedios dentro de los factores principales con distinta letra son significativamente diferentes a un $P < 0.05$.

Paddock	**Proportion of seedlings surviving (Least square mean ± standard error of mean)**
Paddock 30	0.76b ± 0.06
Paddock 31	0.26a ± 0.10
Time of seedling emergence	
19 February	0.46 ± 0.13
13 March	0.61 ± 0.19
2 April	0.41 ± 0.17
16 April	0.51 ± 0.09
25 May	0.60 ± 0.20

DISCUSSION

This study highlighted the success of natural reseeding of plantain in a sward mix containing; plantain, chicory, red clover and white clover. Plantain seedling emergence varied between paddocks and gradients over time, with seedling numbers ranging between 17-368 seedlings per m^2. In general, seedling emergence appeared to be higher on the >15° slope than on flat ground, likely a consequence of the lower average ground cover (live herbage material) on the slope. Previous studies have also observed seedling emergence to be higher in areas with higher percentage of bare ground and/or lacking a canopy (Bullock *et al.*, 1994; Edwards *et al.*, 2005; Gross and Werner, 1982).

Seedling survival is a crucial factor in determining the overall success of a species' ability to recruit seedlings to increase or maintain plant populations. In the current study there was no effect of time of seedling emergence on seedling survival, with 41-61% of all seedlings surviving. In a similar manner, plantain has also been shown to establish readily when oversown into existing grass-based swards (Douglas *et al.*, 2013; Edwards *et al.*, 2005). Conversely, in prairie grass (*Bromus willdenowii* Kunth.) the survival of seedlings from natural recruitment has been shown to be greater in seedlings with earlier emergence dates (Hume *et al.*, 1990). The level of plantain seedling survival observed in the current study is both significant and useful for persistence. Similarly, Hume and Barker (1991) found the survival of perennial ryegrass seedlings from natural reseeding was substantial, contributing 11% of total tillers to the sward. Whereas, L'Hullier and Aislabie (1988) found that reseeding of perennial ryegrass was only successful under lax grazing management or management which included summer spelling and allowed for the development of reproductive tillers. Conversely, seedling survival one year after natural reseeding has been found to be poor from white clover (4.4%) and prairie grass (1%) (Chapman, 1987; Hume *et al.*, 1990).

In the current study, seedling survival differed between paddocks with survival rates ranging from 26 to 76%. Both paddocks had been managed similarly apart from the paddock with the higher rate of survival having been mechanically mown in the previous spring. The removal of a high post-grazing canopy provided a layer of dead litter in the base of the sward and may, therefore, have created a more suitable environment for the establishment of seedlings. Similarly, Tozer *et al.* (2016) found the presence of litter (dead vegetation) enhanced seedling establishment of broadcast grass, herb, and legume seed by over 3-fold. Furthermore, Hamre *et al.* (2010) observed mulching (mowing once a year then leaving the hay in situ after cutting) had a positive effect on the plant density of plantain in semi-naturalised grassland. It is likely that the cut vegetative matter helped to conserve soil moisture and protect developing seedlings from the effects of sun, wind and grazing animals. In a similar manner, Edwards *et al*. (2005) observed that seedling survival was higher where there was vegetation (e.g. tiller bases) at the soil surface than where seedlings emerged in exposed areas of bare ground. Furthermore, in this study no slugs were observed in the sward. However, anecdotal evidence suggests slugs will graze plantain seedlings in both establishing and mature swards. Therefore, if successful plantain reseeding is to be encouraged, monitoring of the sward for slugs is advised and if slug densities are high pesticide treatment may be required to protect vulnerable plantain seedlings.

After the first grazing in spring, plantain seedlings contributed 14% of the total plantain shoots in the sward and plantain shoot density had generally either increased or remained stable with the exception that in study 1, shoot density in paddock 31 slightly decreased from the start of the study. Combined, these results indicate that natural reseeding enabled plantain to either maintain or increase its density within the sward. At the same time, on the whole, the plant density of chicory declined during the study period. This decline would have allowed more space for plantain seedling recruitment. This effect has been previously observed by Cranston *et al.* (2015b), where the proportion of plantain increased as the proportion of chicory in the sward declined. Similarly, Ayala *et al*. (2011a) and Ayala *et al*. (2011b) have observed natural reseeding in plantain swards and suggested that the process acts as a mechanism to maintain plant density. This degree of success has rarely been observed in other pasture species, particularly in New Zealand grazing systems. In prairie grass swards natural reseeding has been found to contribute to 28% of the plant population and 11% of the total tillers 12 months following reseeding, however, overall plant density declined over the measurement period (Hume *et al.*, 1990). In contrast, in perennial ryegrass swards, while deferred grazing during summer increased tiller density by approximately 50% the following spring, no difference was found 12 months after the deferred grazing (Mccallum *et al.*, 1991). However, further research is advised to quantify the long-term benefits of natural reseeding of plantain. Plantain does not have a seed bank of great longevity (Tonsor *et al.*, 1993), therefore, the majority of seeds germinate in the autumn, while a small proportion of seeds are dormant and survive to germinate in the following spring.

Grazing by livestock can affect seedling recruitment in pastures through a variety of mechanisms including alteration of seed fall by consumption of the seedhead, creation of gaps in the sward to assist establishment and direct grazing of seedlings (Bullock and Marriott, 2000). Grazing management was not altered in the current study to facilitate the natural reseeding of plantain. However, given that the paddocks were not grazed during winter, or grazed below 7 cm, as per best management practice for plantain dominant swards (Ayala *et al.*, 2011a; Cranston *et al.*, 2015a), this may have been beneficial to the survival of seedlings. Regardless, the success of natural reseeding in this study suggests that no change in spring or summer management is needed to enable successful plantain seedling recruitment. Conversely, in many other species, paddock closure or summer spelling is required to encourage both seedhead and seedling numbers in order to successfully achieve natural reseeding (Hume and Barker, 1991; L'hullier and Aislabie, 1988; Mccallum *et al.*, 1991). The reseeding success of plantain under regular grazing is possibly because livestock are reluctant to graze mature plantain seedheads (Pain *et al.*, 2015), thereby giving plantain the opportunity to release seed and enable reseeding.

The features of plantain seed and its germination strategy are likely the key reasons why plantain is successful at reseeding naturally. Plantain seeds produce a sticky mucilage when wet (Grime *et al.*, 1988), which encourages the uptake and retention of moisture around the seed, to ensure that sufficient moisture is available for germination. Furthermore, plantain seeds rapidly develop a critical root mass before allocating more of their energy to shoot growth (Sanderson and Elwinger, 2000). In sown swards, plantain seedling development is relatively fast but is heavily influenced by temperature and moisture (Powell *et al.*, 2007; Sanderson and Elwinger, 2000). Combined, these features of plantain mean that its seedlings are fast developing and vigorous during establishment, and consequently capable of successful natural reseeding in an established sward.

CONCLUSION

Our results demonstrate that natural reseeding of plantain occurred at significant levels under conventional grazing management in a sward mix containing plantain, chicory, red clover and white clover. The number of plantain seedlings which emerged and the survival rate of seedlings varied between the paddocks, but it was still considerable in the poorer paddock. This suggests that farmers could utilise the successful natural reseeding of plantain as a management option to 'thicken-up' existing swards of plantain.

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