Companion legume species maximise productivity of chicory (*Cichoruim intybus*)

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Abstract

Chicory is a productive perennial forage herb that is well adapted to a range of environments across southern Australia. Chicory needs nitrogen (N) supply from either inorganic fertiliser, or a companion legume. The objective of this study was to test the suitability of lucerne (*Medicago sativa*), balansa clover (*Trifolium michelianum*), arrowleaf clover (*T. vesiculosum*), and subterranean clover (*T. subterraneum*) as companion legumes in chicory-based pastures. Two field experiments were established adjacent to each other at Morongla near Cowra, New South Wales in 2008 and 2009. Pasture establishment, persistence, herbage production and botanical composition were assessed over 3 years. Results showed that chicory pastures mixed with annual legumes, either a single species or a mixture of 3 annual legume species produced more pasture DM compared to a pure chicory stand or lucerne/subclover pasture. Chicory mixed with aerial seeded legumes was more productive, but can create a dilemma for grazing management in spring. It is suggested that 10-15% legume component in chicory-based pastures would be enough to meet the N requirement for the optimal growth of chicory in spring. The growth of chicory was suppressed greatly by lucerne and gradually the sward became dominated by lucerne in year 3, indicating that lucerne was an incompatible companion species for chicory, most probably due to superior competition for moisture.

Introduction

Chicory (*Cichoruim intybus*) has been identified as a new perennial forage species that is more tolerant to acidic and waterlogged soils than lucerne (*Medicago sativa*) in the medium and high rainfall zones of southern Australia (Dear *et al.* 2008). Chicory is highly productive under favourable conditions in spring and summer (Li *et al.* 2010). Being a perennial herb, chicory needs nitrogen (N) supply for its growth from either inorganic fertiliser or a companion legume species. With the high costs associated with fertiliser and application, it is logical to grow a legume species with chicory as a companion species. The ideal companion species should not only have complementary seasonal growth to chicory, but also have different morphological characteristics, both aboveground and belowground, to minimize competition between the two species. The winter active species can compensate for the low growth activity of chicory during the cool season. However, grazing in winter can be detrimental to the persistence of chicory. Since the release of its first forage cultivar 'Grasslands Puna' in 1985 (Rumball 1986), a range of grass and legumes species have been grown in mixtures with chicory across various environments (Martensson *et al.* 1998; Kunelius and McRae 1999; Alemseged *et al.* 2003). It remains a challenge to select the best companion species. The objective of this study was to test the suitability of arrowleaf clover (*Trifolium vesiculosum*), balansa clover (*T. michelianum*), and subterranean clover (*T. subterraneum,* subclover) and lucerne as companion legume species for chicory-based pastures in medium-high rainfall zone of southern Australia.

Materials and Methods

Two field experiments were established adjacent to each other at Morongla

(near Cowra), New South Wales in autumn 2008 (Experiment 1) and 2009 (Experiment 2) (148°41'29"E, 33°50'2"S). The soil at the site was a yellow Chromosol (Isbell 1996). Soil pH in 1 M KCl was 5.5 in 0-10 cm and 4.5 in 10-20 cm, Colwell P was 49 and 32 mg/kg at the 0-10 and 10-20 cm depths, respectively. The long-term rainfall was 573 mm. Rainfall was well below average in 2008 (481 mm) and 2009 (417 mm), but 66% and 10% greater than average in 2010 (954 mm) and in 2011 (629 mm), mainly as summer storms in February and late spring in November and December.

There were 7 treatments with 4 replicates in a complete randomized design. Chicory was mixed with 1 of 3 annual legume species (arrowleaf clover, balansa clover and subclover) individually, or a mix of all 3 annual legumes, or mixed with lucerne and subclover. A pure chicory stand and a lucerne and subclover mix were also included as controls. The sowing rates were 4 kg/ha for chicory, 2 kg/ha for arrowleaf clover and balansa clover, 7 kg/ha for subclover, 5 kg/ha for lucerne for individual mixes. For chicory/lucerne/subclover mix, chicory and lucerne sowing rates were reduced to 2 and 2.5 kg/ha, respectively, with 7 kg/ha subclover. For chicory/annual legume mix, chicory was sowed at 2 kg/ha, arrowleaf and balansa at 0.5 kg/ha each, subclover at 3.5 kg/ha. Plot size was 4 × 12 m^2.

Establishment counts were conducted 8 weeks after sowing. Basal frequency (presence of crown or stem base in 10 × 10 cm grids in a 1-m^2 quadrat) of chicory and lucerne was measured in 2 fixed quadrats in autumn over 3 years from year 2 onwards as an indication of persistence. Pasture dry matter (DM) production was visually estimated each season and calibrated by 10 quadrat cuts which represented the full range of scores assigned at a given sampling ($r^2 > 0.8$, $P < 0.05$). Botanical composition was measured using Botanal technique (t Mannetje and Haydock 1963) whenever pasture DM was measured. All data were subjected to appropriate analysis of variance conducted in GenStat Release 14.1.

Results

The establishment was satisfactory for both experiments despite drought years in 2008 and 2009. Averaged across two experiments, seedling numbers of chicory were 83 plants/m^2 for the pure stand, 64 plants/m^2 for mixtures with annual legumes and 28 plants/m^2 for the mixture with lucerne. Lucerne seedlings were 30 plants/m^2 for the chicory/lucerne mixture and 48 plants/m^2 for lucerne/subclover pasture. The initial establishment of the annual legume components ranged from 53-119 plants/m^2 (data not shown).

The basal frequency decreased by 34% for the pure chicory stand, 38%-59% for all chicory mixtures and 31%-39% for lucerne from years 2 to 4 in Experiment 1 (Table 1). In contrast, basal frequency of chicory increased up to 105% from years 2 to 4 for all chicory mixtures, but basal frequency of chicory in chicory/lucerne/subclover mixture decreased by 28% while basal frequency of lucerne in the same mixture increased 25% during the same period in Experiment 2 (Table 1). For lucerne/subclover mixture, basal frequency of lucerne increased by 10% from years 2 to 4 in Experiment 2.

Table 1 Persistence measured as basal frequency (%) over 4 years for pastures sown in 2008 and 2009

	Chicory				Lucerne			
Experiment 1 (sown in 2008)	Year 2	Year 3	Year 4	ChangesA	Year 2	Year 3	Year 4	Changes
Pure chicory	28.8	22.8	18.9	-34%	-	-	-	-
Chicory/arrowleaf clover	26.4	18.4	13.6	-48%	-	-	-	-
Chicory/balansa clover	29.3	22.1	15.5	-47%	-	-	-	-
Chicory/subclover	29.3	19.6	14.6	-50%	-	-	-	-
Chicory/annual legumes mix	26.0	19.9	16.3	-38%	-	-	-	-
Chicory/lucerne/subclover	15.1	4.6	6.3	-59%	24.1	29.8	14.8	-39%
Lucerne/subclover	-	-	-	-	35.6	41.8	24.6	-31%
Experiment 2 (sown in 2009)								

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Pure chicory	17.8	15.6	28.8	62%	-	-	-	-
Chicory/arrowleaf clover	16.5	16.6	25.8	56%	-	-	-	-
Chicory/balansa clover	20.8	12.4	28.3	36%	-	-	-	-
Chicory/subclover	15.3	12.5	30.3	105%	-	-	-	-
Chicory/annual legumes mix	14.8	13.6	24.5	61%	-	-	-	-
Chicory/lucerne/subclover	9.8	3.4	7.0	-28%	17.0	23.5	21.3	25%
Lucerne/subclover	-	-	-	-	29.3	29.9	32.3	10%

[A]Percentage changes from years 2 to 4; -, not applicable.

The two experiments had contrasting patterns of pasture DM production, reflecting the distribution of rainfall received at the site. In Experiment 1, accumulated pasture DM for sown species increased over years. The pasture DM was more than doubled in year 3 (2010) compared to those in year 2 (2009) for all treatments. It was extremely wet in 2010. In Experiment 2, pasture DM was up to 31.5 t/ha in year 2 (2010), but halved in year 3 (2011) for most of treatments (Fig. 1).

In Experiment 1, there were significant differences in pasture DM for sown species between treatments ($P < 0.05$) (Fig. 1). Chicory mixed with arrowleaf clover and balansa clover had significantly higher pasture DM than the mixture with subclover, pure chicory stand and lucerne pastures in all years. In Experiment 2, there was a significant pasture and year interaction in pasture DM ($P < 0.05$). Chicory/balansa clover had the highest pasture DM in year 2 (31.5 t/ha), but lowest in year 3 (13.6 t/ha). Lucerne/subclover had the lowest pasture DM in year 2 (25.4 t/ha), but had the second highest pasture DM in year 3 (16.2 t/ha) where chicory/annual legume mix had the highest pasture DM (16.4 t/ha).

Averaged across all chicory and annual legume mixtures, legumes comprised more than 30% of the mixture in year 1 and this percentage was maintained at 15% in years 2 and 3 in Experiment 1 (Fig. 2*a*). In contrast, in Experiment 2, the legume component decreased sharply from 34% in year 1 to 10% in year 2 and 6% in year 3 (Fig. 2*b*). The proportion of chicory in the mixture was the lowest in year 1 and peaked in year 2 before decreasing in year 3 in Experiment 2. The proportion of lucerne increased each year in both the chicory/lucerne/subclover mix and lucerne/subclover mix. For example, the proportion of lucerne increased from 21% in year 1, to 46% in year 2 and reached 67% in year 3 for the chicory/lucerne/subclover mixture in Experiment 2 (Fig. 2 *b*). Weeds comprised less than 27% in year 1, and was less than 15% in years 2 and 3 for both experiments (Fig. 2).

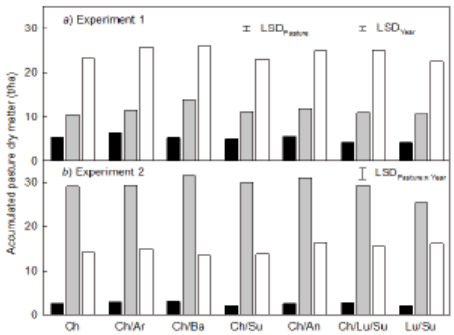

Fig. 1 Accumulated pasture dry matter (t/ha) for sown species in year 1 (□), year 2 (▒) and year 3 (■) in *a*) Experiment 1 sown in 2008 and *b*) Experiment 2 sown in 2009. Ch, pure chicory; Ch/Ar, chicory/arrowleaf clover; Ch/Ba, chicory/balansa clover; Ch/Su, chicory/subclover; Ch/An, chicory/annual legumes mix, Ch/Lu/Su, chicory/lucerne/subclover and Lu/Su, lucerne/subclover.

concerned about pasture productivity decline.

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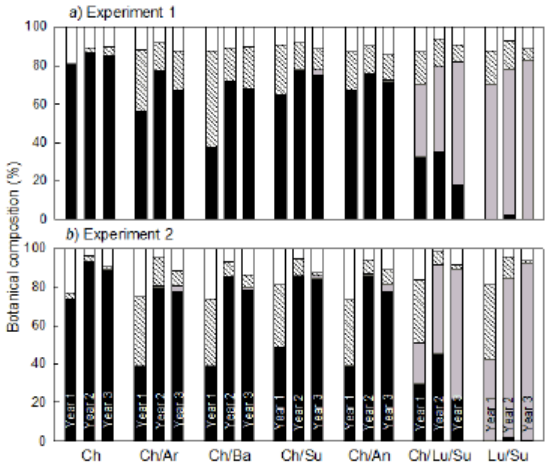

Fig. 2 Pasture botanical composition (chicory; lucerne; annual legumes; weeds) in *a*) Experiment 1 sown in 2008 and *b*) Experiment 2 sown in 2009. The first bar in each treatment is for the botanical composition in year 1, and the second bar in year 2 and the third bar in year 3 as shown in the graph. The treatment notation is the same as in Fig. 1.

Discussion

Chicory, when either mixed with 3 annual legume species individually, or included in a mixture of all 3 annual legume species, produced more pasture DM compared to pure chicory stand and lucerne/subclover pasture (Fig. 1). The companion legume species not only fills the feed gaps in winter when chicory is least productive, but also supplies N for chicory through N fixation. In addition, chicory's superior ability to scavenge for N would increase the level of biological N fixation by companion legumes as suggested by Gardner et al. (2010). It appears that a legume composition of 10-15% in chicory-based pastures would be adequate to meet the N requirement for the fast growth of chicory in spring although Dove (1989) suggested that optimum legume content of pastures should be 20-45% for maximum animal production.

When chicory was mixed with lucerne, the growth of chicory was suppressed greatly and lucerne dominated the sward by year 3 (Fig. 2). This indicates that lucerne was an incompatible companion species for chicory, most probably due to superior competition for moisture (Hayes *et al.* 2010). All 3 annual legume species tested in the current study were found to be suitable as companion species for chicory. However, when chicory was mixed with the two aerial seeded legume species, arrowleaf clover and balansa clover, it would present a dilemma for grazing management in late spring when legumes set seed while chicory has peak DM production, which needs to be heavily grazed.

Chicory has a reputation of poor persistence. Anecdotally, it only lasts for 2-3 years. Li *et al.* (2010) suggested that persistence may be closely related to abiotic conditions, such as soil moisture, rather than genetics. During the experimental period, we had two consecutive wet years in 2010 and 2011. As a result, the proportion of chicory was over 85% in the pure stand and greater than 70% in chicory and annual legume mixtures in year 3 in both experiments (Fig. 2). In addition, the basal frequency increased by 36%-105% from years 2 to 4 in Experiment 2 and maintained at 14%-20% in year 4 in Experiment 1 (Table 1). Furthermore, it was observed that a substantial number of chicory seedlings were regenerated in autumn in year 4 in Experiment 2. Under these conditions, chicory was likely to be productive and persistent for 4 years or longer. This result is consistent to the finding from a chicory cohort study conducted in Hamilton, Victoria (Li *et al.* 2010). It is worthwhile to mention that the inappropriate grazing management would shorten the longevity of chicory pasture significantly which is beyond the scope of this study.

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