The herbage accumulation and nutritive value of birdsfoot trefoil (*Lotus corniculatus* l.) cultivars

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Abstract

Lotus corniculatus L. is an alternative species of high nutritive value adapted to stressful environments. Despite large variations in climate and soil conditions, the only cultivar currently in use in New Zealand is the winter dormant 'Grasslands Goldie'. This paper reports an evaluation of alternative winter active cultivars in Uruguay (33° 54'). Winter active cultivars were 2.3 times more productive than winter dormant cultivars. Under regular defoliation, organic matter digestibility (OMD) was maintained over 600 g/kg DM. Under extended herbage accumulation, OMD declined with advanced maturity, associated with a decline in leaf proportion. The digestible organic matter accumulation increased from the vegetative to the late maturity stages for the cultivar INIA Draco, remained unchanged after 50 % flowering in San Gabriel and Grasslands Goldie and was unchanged over all stages tested in the cultivar Steadfast. CT varied from 21.6 to 30.7 g/kg DM between cultivars, being within the recommended range that produces benefits to animal performance. It is suggested that winter active cultivars deserve further consideration for the North Island of New Zealand.

Additional Key Words: Condensed tannins, lotus, Grassland Goldie.

Introduction

Birdsfoot trefoil (*Lotus corniculatus* L., BFT) has had limited use in New Zealand farming, attributable to its poor tolerance to grazing, and a poor competitive ability in comparison with traditional legumes in the commonly used pasture mixtures. However, high nutritive value of BFT forage coupled with its condensed tannins concentration have renewed interest (Waghorn *et al.*, 1998) in its use in intensive livestock systems in recent years, expanding its traditional role for stressful environments (Scott and Charlton, 1983).

BFT can be used as a supplementary feed source in periods where the growth or nutritive quality of commonly used pasture mixtures declines, or as a specialist crop that provides a high quality protein bank for special purposes.

BFT has high nutritive value and declines less rapidly in quality than some other species when mature (Smith, 1964; Taylor *et al.*, 1973; Marten and Jordan, 1979), adding flexibility to management strategies. Extensive research in New Zealand, testing the potential advantages of herbage containing condensed tannins has shown concentrations between 20-40 g/kg DM in BFT produce a series of beneficial effects in animal nutrition in comparison with diets without tannins (Barry, 1989; Barry and Mc Nabb, 1999). In this context, the nutritive value of BFT during the grazing season, and changes that occur due to herbage accumulation or maturity stages, will have a significant impact on animal performance.

Opportunities for BFT in the range of environmental variations in New Zealand are limited because Grasslands Goldie is the only commercially cultivar available. The objectives of the experiment were to extend the available information on the effect of physiological growth stages and seasons on the herbage accumulation and nutritive value of BFT cultivars. The evaluation was carried out in Uruguay, comparing cultivars from Uruguay, Brazil and the USA with Grasslands Goldie from New Zealand.

Materials and Methods

The experiment was conducted at Palo a Pique Research Unit, INIA Treinta y Tres, Uruguay (latitude 33° 54' S, longitude 54° 38' W), on a fine, thermic, mixed, vertic Argiudoll soil, moderately fertile, with 3.0 μg/g soil of phosphorus (Bray I) and pH 5.4. Two winter active cultivars of BFT of Latin American origin (INIA Draco and San Gabriel) and two introduced winter dormant cultivars (Grasslands Goldie and Steadfast, from New Zealand and USA respectively) were evaluated for herbage production and nutritive value under cutting management. The four cultivars were established in 5 x 2.5 m plots in May 8, 1998, at a seeding rate of 12 kg/ha, and superphosphate was applied at 26 kg P/ha. Plots were cut at 40-day intervals with a reciprocating blade mower to either 4 cm or 8 cm above ground level following a first cut taken at the vegetative, the 50 % flowering or the advanced maturity stages (4 November, 15 December and 25 January for the winter active cultivars and 4 December, 13 January and 22 February for the winter dormant cultivars) in a 4 (cultivar) x 2 (cutting height) x 4 (replicates) experiment. Results are presented for estimates of herbage production and organic matter digestibility (OMD) made throughout the period May 1998-April 1999 and condensed tannins concentration (CT) in September 1999. Pooled results for the cutting heights are presented.

Estimates of herbage production were made from a central 1 m x 5 m strip in each plot. *In vitro* organic matter digestibility (OMD) (Tilley and Terry, 1963) was determined at the initial defoliation times for the treatments and at 40-day intervals during the first cutting season, at the Nutrition Laboratory of INIA La Estanzuela, Uruguay.

Two forage samples of each cultivar were hand clipped at the vegetative stage, stored at –20 ^{0}C, dried and ground to pass through a 1 mm sieve. CT fractions (acetone/water extractable, protein-bound and fibre-bound) were determined using the butanol-HCL method of Terril *et al.,* (1992) at the Institute of Food Nutrition and Human Health, Massey University, Palmerston North (Juan Mieres, personal communication).

Results and Discussion

Herbage production of the winter active cultivars (INIA Draco and San Gabriel) was higher than that of the winter dormant cultivars (Grasslands Goldie and Steadfast) in all seasons of the year, with annual herbage accumulation being 2.6 times greater (6290 vs 2400 kg DM/ha/year, SEM 160, P<0.01). There were no differences between cultivars within each group (Table 1).

The herbage accumulation from sowing to the three physiological growth stages defined (vegetative, 50 % flowering and advanced maturity) differed between groups (Table 1). The winter active cultivars reached equivalent physiological growth stages four weeks earlier than winter dormant cultivars. Accumulation to the vegetative stage differed between winter active cultivars with San Gabriel accumulating 2.3 times more than INIA Draco (P<0.01). Between winter dormant cultivars, Steadfast accumulated significantly (P<0.05) more herbage mass than Grasslands Goldie to the vegetative stage (Table 1). At 50 % flowering, differences in accumulation remained in favour of San Gabriel in the winter active group (P<0.01), but there were no differences within the winter dormant group (Table 1). At advanced maturity, there were no differences between cultivars in either group (Table 1).

Table 1. Annual herbage accumulation (kg DM/ha/year) in the year of establishment of birdsfoot trefoil cultivars, and herbage accumulation (kg DM/ha) from sowing (8 May, 1998) to different physiological growth stages.

	Annual Accumulation	Vegetative	50 % Flowering	Advanced maturity
Winter active cultivars	**May 1998- April 1999**	**4 November (180 days)**	**15 December (221 days)**	**25 January (262 days)**
INIA Draco	6120	700	2370	3360
San Gabriel	6460	1630	2690	3360
SEM	153	105	56	132
Significance	NS	**	**	NS
Winter dormant cultivars	**May 1998- April 1999**	**4 December (210 days)**	**13 January (250 days)**	**22 February (290 days)**
Grasslands Goldie	2430	760	1720	1850
Steadfast	2380	1060	1580	1950
SEM	103	75	119	120
Significance	NS	*	NS	NS

**, P<0.01; *, P<0.05; NS, not significant; SEM, standard error of the mean; ; (n) number of observations for each treatment mean.

Nutritive value under regular defoliation

Over the season, the OMD of cultivars tested was maintained over 600 g/kg when defoliated at regular intervals of 40 days. Between winter active cultivars, there were differences at two of the four times tested ($P<0.01$ in both cases), with the OMD of INIA Draco greater than that of San Gabriel (Table 2). Between winter dormant cultivars, there were differences at two of the three times studied (Table 2). At the first sampling, OMD of Grasslands Goldie was higher than that of Steadfast ($P<0.01$), but Steadfast had higher OMD than Grasslands Goldie at the end of the season ($P<0.05$) (Table 2).

Table 2. Organic matter digestibility (g/kg DM) of four birdsfoot trefoil cultivars under regular defoliation each 40 days during the growing season.

	Defoliation periods			
Winter active cultivars	**4 Nov–15 Dec**	**15 Dec-25 Jan**	**25 Jan-8 Mar**	**8 Mar-15 Apr**
INIA Draco	666	616	633	686
San Gabriel	628	602	612	682
SEM (n)	4.1 (8)	5.2 (8)	1.7 (8)	5.8 (8)
Significance	**	NS	**	NS
Winter dormant cultivars	-	**4 Dec-13 Jan**	**13 Jan-22 Feb**	**22 Feb-5 Apr**
Grasslands Goldie		652	669	647
Steadfast		616	659	664
SEM (n)		3.1 (8)	3.8 (8)	4.0 (8)
Significance		**	NS	*

**, P<0.01; *, P<0.05, NS, not significant; SEM, standard error of the mean; ; (n) number of observations for each treatment mean

Nutritive value of accumulated herbage

OMD declined with increasing maturity in all cultivars, except San Gabriel which had an increased OMD from the vegetative to the 50 % flowering stage (Table 3). Between the winter active cultivars, INIA Draco had higher OMD than San Gabriel at the vegetative and late maturity stages ($P<0.01$ in both cases), but San Gabriel had higher OMD at 50 % flowering (Table 3). The leaf/(leaf+stem) ratio declined as the plants matured (0.64, 0.53 and 0.37 for vegetative, 50 % flowering and advanced maturity, respectively), but there were no differences between the winter active cultivars ($P<0.01$, data not presented, see Ayala, 2001).

Table 3. Organic matter digestibility (g/kg DM) of four birdsfoot trefoil cultivars harvested at three physiological growth stages after sowing.

	Vegetative	50 % Flowering	Advanced maturity	SEM (time)/ Significance
Winter active cultivars	4 November (180 days)	15 December (221 days)	25 January (262 days)	
INIA Draco	666	638	550	
San Gabriel	636	651	505	3.13 **
SEM (n)	2.0 (8)	3.0 (8)	3.4 (8)	
Significance	**	*	**	
Winter dormant cultivars	4 December (210 days)	13 January (250 days)	22 February (290 days)	
Grasslands Goldie	665	629	532	
Steadfast	663	556	499	3.11 **
SEM (8)	2.5 (8)	4.5 (8)	1.0 (8)	
Significance	NS	**	**	

**, P<0.01; *, P<0.05, NS, not significant; SEM, standard error of the mean; (n) number of observations for each treatment mean

The winter dormant cultivars showed no differences in OMD at the vegetative stage, but Grasslands Goldie had higher OMD than Steadfast at 50 % flowering and at advanced maturity (Table 3). The leaf/(leaf+stem) ratio showed the same pattern as observed for winter active cultivars, declining significantly as the plants matured (0.64, 0.55 and 0.40 for vegetative, 50 % flowering and advanced maturity, respectively) (P<0.01, data not presented, see Ayala, 2001).

The accumulation of digestible organic matter (DOMA: herbage dry matter accumulation, corrected for ash content, multiplied by organic matter digestibility) differed between cultivars and physiological stages. DOMA is presented for cultivars individually with the levels of dry matter accumulation and OMD in Figure 1 a-d. DOMA increased progressively from vegetative to late maturity in INIA Draco (0.4 to 1.8 t DOMA/ha, P<0.01). For San Gabriel and Grasslands Goldie, DOMA increased from vegetative to 50 % flowering but remain unchanged at late maturity (1.0, 1.7 and 1.7 t DOMA/ha, for San Gabriel (P<0.01), and 0.5, 1.1 and 1.0 t DOMA/ha for Grasslands Goldie (P<0.05), for the three physiological stages, respectively). For Steadfast, DOMA was the lowest and showed little change over the different physiological stages (0.8 t DOMA/ha on average). Lopez *et al.,* (1965) reported that the digestibility of leaves in BFT remained approximately constant from early growth to full flowering (75 %), but stem digestibility declined from 61 % during vegetative to 50 % at full flowering. After flowering, there is a reduction in leaf proportion and an increase in the lignin content of stems (Lopez *et al.,* 1965). The DOMA results suggested that there was no benefit in accumulating feed past the 50 % flowering stage (Figure 1).

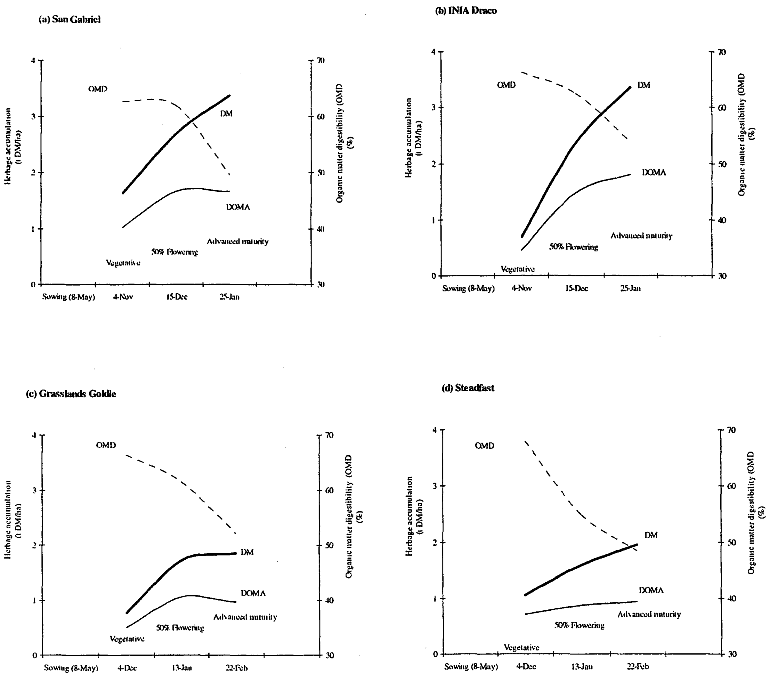

Figure 1. Changes in dry matter harvested (DM), organic matter digestibility, (OMD) and digestible organic matter (DOMA) of four birdsfoot trefoil cultivars from sowing to three physiological growth stages.

The winter active cultivars, San Gabriel and Draco, had substantially greater levels of herbage production than the winter dormant cultivars, Grasslands Goldie and Steadfast, at all seasons of the year and at equivalent levels of nutritive value. Frost damage affected the performance of the winter active cultivars evaluated in New Zealand (Charlton *et al.,* 1978; Widdup *et al.,* 1987), and Grasslands Goldie is currently the only cultivar available here. However, the overlap in latitude between Uruguay (30-35°S) and New Zealand (33-47°S) suggests that there should be scope to at least use the more productive winter active genotypes in the North Island.

Condensed tannins content

Total CT concentrations at the vegetative stage in the second spring (September 1999) showed differences (P<0.05) between cultivars, with San Gabriel having the highest concentration, Grasslands Goldie and INIA Draco being intermediate and Steadfast the lowest (Table 4). Over 86 % of CT was bound (Table 4), with the largest component being protein-bound, attributable to the methodology used (T.N. Barry, personal communication). CT concentrations of all tested cultivars were within the recommended range of 20-40 g/kg DM that produces beneficial effects such as eliminating bloat and increasing the absorption of protein from the small intestine (Barry, 1989; Waghorn *et al.,* 1990; Barry and Mc Nabb, 1999).

Table 4. Condensed tannin (CT, g/kg DM) concentrations of four birdsfoot trefoil cultivars at the vegetative stage in spring.

Cultivars	Extractable CT	Protein-bound CT	Fibre-bound CT	Total CT	Bound CT (% total)
San Gabriel	4.2	25.1	1.4	30.7	86.3
INIA Draco	4.3	20.7	0.9	25.9	83.4
Grasslands Goldie	2.5	19.7	1.8	24.0	89.6
Steadfast	3.4	16.8	1.4	21.6	84.2
SEM (n)	0.58 (2)	1.48 (2)	N/A	0.97 (2)	--
Significance	NS	(0.097)		*	

*, P<0.05; NS, not significant; N/A, not replicates for statistical analysis; SEM, standard error of the mean; (n) number of observations for each treatment mean.

Conclusions

The main conclusions were:

1. The maintenance of acceptable levels of organic matter digestibility, even under extended periods of accumulation, suggested that BFT is an appropriate species for forage bank accumulation as it maintained its nutritive value until 50 % flowering. Under regular defoliation, high nutritive value was maintained throughout the growing season. There were differences in the seasonal accumulated herbage mass and nutritive value of the four birdsfoot trefoil cultivars.

2. Herbage production of the winter active cultivars was greater than that of the winter dormant cultivars under Uruguayan conditions. It is suggested that Latin American material should re-evaluated for the North Island of New Zealand to extend the growing season into winter.

3. The rhizomatous cultivar, Steadfast, had similar herbage production to that of Grasslands Goldie.

4. The condensed tannins concentrations of the four cultivars were within the recommended range of 20-40 g/kg DM that contributes to enhanced animal performance.

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