Promotion of *Lotus tenuis* and calf early weaning as a good management practice for breeding herds in marginal soils of the Flooding Pampa (Argentina)

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ABSTRACT

The promotion of forage legumes in marginal environments for agriculture constitutes a major technological challenge for livestock farming. The legume *Lotus tenuis* (*Waldst. & Kit.*) is a good example of beneficial naturalization in the Salado River Basin, that is, in the largest area dedicated to bovine farming in the country. The aim of this study was to evaluate the promotion of *L. tenuis* in marginal areas as a valuable alternative for early weaning systems in livestock production. Two treatments were tested during three study periods. To evaluate the efficiency of the proposed system, average daily weight gain (DWG) and weight gain (WG) of conventional weaning (CW) and early weaning (EW) calves were determined and compared. EW calves grazing on *L. tenuis* gained more weight than CW calves during Study period 1 ($P = 0.028$), but no differences were observed between treatments during Study periods 2 and 3 ($P > 0.05$). Body Condition Score (BCS) for dams in both treatments was evaluated. For all three study periods, BCS improvement was higher in cows from the EW treatment than in Lactating cows (LC) from the CW treatment. Thus, EW improved cow BCS and did not generate weight reductions in calves thanks to the Lotus-based diet. In conclusion, *L. tenuis* promotion in the summer season resulted higher yields in marginal areas than semi–natural pastures. It also provided an acceptable nutritional value to properly fed a considerable amount of calves on a small surface area, and enabled a better recovery of the dams in terms of body condition. The obtained results support the design of an easy-to-use strategy that facilitates adoption by producers.

Keywords: biomass, pastures, legumes, livestock.

RESUMEN

La promoción de leguminosas forrajeras en ambientes marginales para la agricultura constituye un importante desafío tecnológico para la ganadería. Lotus tenuis (Waldst. & Kit.) es un buen ejemplo de naturalización beneficiosa en la Cuenca del Río Salado, es decir, en una de las más importantes regiones dedicada a la cría de bovinos en el país. El objetivo de este estudio fue evaluar la promoción de L. tenuis como una alternativa valiosa para los sistemas de destete temprano en la producción ganadera. Se probaron dos tratamientos durante tres períodos de estudio. Para evaluar los beneficios del sistema propuesto, se determinó y comparó la

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ganancia de peso diario promedio y la ganancia del peso de terneros según se utilizaran procesos al pie de la vaca o con un destete temprano. Los terneros provenientes de un destete temprano que pastaban en promociones de L. tenuis ganaron más peso que los terneros provenientes de un destete convencional durante el período de estudio 1 (P = 0.028), pero no se observó diferencia entre los tratamientos durante los períodos de estudio 2 y 3 (P > 0.05). Se evaluó la puntuación de condición corporal para las madres en ambos tratamientos. Para los tres períodos de estudio la mejora de esta condición fue mayor en las vacas del tratamiento de destete temprano que en las vacas lactantes del tratamiento convencional. Por lo tanto, el destete temprano mejoró la condición corporal de la vaca, sin generar reducciones de peso en los terneros gracias a la dieta basada en L. tenuis. En conclusión, la promoción de esta leguminosa en la temporada de verano proporcionó mayores rendimientos en áreas marginales para la agricultura que las pasturas seminaturales. Asimismo, proporcionó una dieta con un valor nutricional aceptable para la alimentación adecuada de una cantidad considerable de terneros en una superficie pequeña, permitiendo al mismo tiempo, una mejor recuperación de las madres en términos de condición corporal. Los resultados obtenidos respaldan el diseño de una estrategia sencilla que facilita la adopción por parte de los productores.

Palabras clave: *biomasa forrajera, pasturas, leguminosas, ganado vacuno.*

INTRODUCTION

Allowing weaning to occur when calves reach an age of 6–8 months is a common practice in beef cow–calf operations (Pate *et al*., 1985; Thrift and Thrift, 2004). On rangelands, however, this practice may be hampered by a rapid decline in the quantity and quality of forage resources as a consequence of lignification, temperature increase, or drought in mid– or late–summer (Mulliniks *et al*., 2013).

During this period, cow–calf pairs present their highest energy requirement due to lactation and cow pregnancy. Early weaning (EW, when the calf is 4–5 months old) is acknowledged as a viable alternative to counter summer quality forage shortage (Whittier, 1995; Merrill *et al*., 2008; Warner *et al*., 2015). It has been also shown that EW decreases nutrient requirements of beef cows, enabling an improvement in cow Body Condition Score (BCS) (Merrill *et al*., 2008; Odhiambo *et al*., 2009; Martins *et al*., 2012; Waterman *et al*., 2012) and increasing pasture carrying capacity (Johnson *et al*., 2015).

EW can also increase conception rates and shorten the interval from parturition to conception in calf heifers (Laster *et al*., 1973; Lusby *et al.,* 1981). Despite the advantages of this practice, EW is a source of stress for the dam and for the calf. This effect is especially acute and prolonged for the calf, which at weaning is subjected to multiple stressors such as the loss of the mother and access to the udder and milk, and changes in the social and physical environment (Enríquez *et al*., 2011).

In recent years, researchers have reported the use of diverse forage species such as *Cynodon dactylon* (L.), *Chloris gayana* (Kunth.), *Medicago sativa* (L.), *Trifolium repens* (L.), or *Zea mays* (L.) silage (Castells *et al*., 2013; Terré *et al*., 2013; Corriher *et al*., 2014) to compensate for milk restriction to calves during weaning. Interestingly, *Lotu*s species are forage legumes considered to have similar or even higher nutritional value than *M. sativa* and *T. repens* (Montes, 1988; Acuña, 1998; Blumenthal and McGraw, 1999; Cassida *et al*., 2000). Also, these species can either be grazed by livestock or can be used as hay or silage, unlike several other forage legumes that do not offer these possibilities (Blumenthal and McGraw, 1999).

Lotus tenuis (Waldst. & Kit.) is currently being tested as an alternative to overcome summer forage deficiency in the Flooding Pampa, the most important area for calf production in Argentina (Miñón *et al*., 1990; Escaray *et al*., 2012, 2014, 2016). An important advantage of *L. tenuis* when compared to *M. sativa* or other forage legumes is its great adaptability to marginal environments, where waterlogging and saline or alkaline soils often occurs (Escaray *et al*., 2012, 2014, 2016; Antonelli *et al*., 2016; 2019).

This type of soil condition predominates in vast extensions of the Flooding Pampa, where *L. tenuis* is naturalized. In summer, *L. tenuis* is already in reproductive state, but unlike C_3 grasses, it continues to produce leaves with optimal nutritional quality, thus maintaining high levels of digestibility and crude protein (CP) (Hidalgo and Cauhépé, 2009) and reaches its maximum biomass (Colabelli and Miñon, 1994).

Due to these characteristics, *Lotus* promotion has been considered as an alternative to overcome forage deficiency during the summer season (Antonelli *et al*., 2016). However, *L. tenuis* shows low competitiveness during the first stages of implantation (Clua *et al*., 1997). This drawback can be reverted by the application of low doses of herbicides during winter, a practice known as *L. tenuis* promotion. This practice increases light and other resources for its implantation and leads to the dominance of this naturalized legume (Antonelli *et al*., 2016; Nieva *et al*., 2016, 2018, 2019). This practice is currently carried out in small pasture areas so far considered marginal areas for agricultural activities, due to their low productive capacity as a result of their low fertility, recurrence of flooding and salt accumulation.

Research on cow–calf and weaning systems has been well documented in Australia (Tyler, 2012; Tyler *et al*., 2012), USA (Arthington *et al*., 2005; Vendramini *et al.,* 2006), the neotropics (Moore and da Rocha, 1983; Betancourt–López *et al*., 2012), and Argentina (Pordomingo, 2002). However, none of these studies considered calves raised on a *Lotus*–based pastures. This study aimed at evaluating the effect on 1) Average daily weight gain (DWG) and weight gain (WG) of EW calves grazing on promoted *L. tenuis* paddocks compared to unweaned (UW) calves from conventional weaning (CW) treatment grazing on semi–natural pasture, and 2) the recovery of the cows from the EW treatment compared to lactating cows (LC) from the CW treatment in terms of BCS. The *L. tenuis* promotion increases the forage supply in constrained areas characterized by its low nutritional value and legumes presence. This last situation could limit the performance of cows and calves (Minson, 1990). In this study, we inquire into whether promoted *L. tenuis* meets the biomass quantity and quality required for acceptable calf performance.

MATERIALS AND METHODS

Site and Pasture description

The study was conducted at the Chacra Experimental Integrada de Chascomús (CEICh–Ministerio de Agroindustrias de la Provincia de Buenos Aires–Instituto Nacional de Tecnología Agropecuaria, Argentina, 35º45'27"S, 58°3'18"W), which is located in the Flooding Pampa region, during the periods 2010–2011, 2011–2012 and 2012–2013 (Study periods 1, 2 and 3, respectively). This region has a temperate sub–humid climate with mean temperatures averaging 8.5 °C in winter and 21.5 °C in summer, and annual rainfall 850–1050 mm. Short floods of 5–7 cm depth occur at the beginning of almost every spring. Nonetheless, severe droughts may occur in early summer. Soils in the experimental area are Natraquoll type, characterized by an A1 horizon with 3.5% of organic matter and 0.22 mg kg^{-1} of extractable Fe, and by a natric B2t horizon at a depth of 17 cm, with 53.3% clay content (Lavado and Taboada, 1988). Plant communities consist mainly of grasses and Compositae species. Native legumes are largely absent and semi–natural pastures are dominated by *Festuca arundinacea*, *Thinopyrum ponticum*, *Cynodon dactylon*, *L. tenuis,* and *Sporobolus indicus*.

Promoted *L. tenuis* pasture

Glyphosate (N–(phosphonomethyl) glycine; 3.5 l ha^{-1}) was applied on a 2 hectares surface area, followed by two applications of 2,4 DB(4–(2,4–dichlorophenoxy) butyric acid, 1 l ha^{-1}) and a single dose of Quizalofop–p–ethyl (Ethyl(R) –2– [4– (6– chloro–2–quinoxalyloxy) phenoxy] propionate; 1.2 l ha^{-1}), in six or seven annual cycles from June to August. After 4 or 5 years of herbicide application, plant species composition in promoted paddocks shifted, and *L. tenuis* became the dominant species (Nieva *et al*., 2016; 2018; 2019; Druille *et al*., 2017).

Weaning treatments

For comparative purposes, both groups of animals were simultaneously incorporated to the experimental lots: a) use of herbicides to increase the presence and persistence of *L. tenuis* and b) without the use of herbicides (semi-natural pasture). Regarding the load, 2 ha were assigned to the EW calves in the *Lotus* promoted paddocks. The dams from EW animal lots and cows-calf pairs from CW management (one animal per ha), grazed in the semi-natural pasture during 4-5 days, in parcels with availability of 1500 to 2000 kg DM/ha and were removed from parcels with remnants forage between 800 and 1200 kg DM/ha. This animal management protocol was optimized years previous to the EW and CW evaluation.

Two treatments were proposed: (1) CW: cow–calf pairs grazing on semi–natural pasture (LC n = 20; calves n = 20), and (2) EW: calves weaned at the age of 4–5 months, grazing on promoted *L. tenuis* paddocks (calves n = 20) and dams grazing on semi–natural pasture (n = 20).

Measurements were performed in the three growth periods mentioned above: Study period 1, Study period 2, and Study period 3 from February to March according to forage availability. All animals used in this research reached maturity and were included in the CEICh usual livestock productivity cycle.

Animal measurement

In each study period and treatment, Aberdeen Angus calves and dams were used to evaluate the Weight Gain (WG), average Daily Weight Gain (DWG), and Body Condition Score (BCS). At the beginning of each study period and treatment, calf weight averaged 160 kg (initial weight). All calves from both treatments were reweighed (final weight) 25 days after the first weight register during the Study period 1, 34 days later during the Study period 2 and 60 days later during Study period 3. This difference in the test time of each period was due to climatic or technical conditions. DWG was then calculated as [final weight–initial weight]/X days of the study period.

Initial BCS was determined for all LC and EW dams at the beginning of treatments. BCS refers to the relative amount of subcutaneous body fat or energy reserve in the cow. It was estimated by visual appraisal and scores were assigned from 1 to 5, where 1 = a very thin cow and 5 = an excessively fat one. At the end of each experiment, BCS determination was repeated on the same cows. BCS change in the period was calculated as final BCS–initial BCS.

Pasture measurement

Plant biomass was harvested from ten 0.25 m^2 quadrats. Plant samples were collected six times during the growing season (October to March) for all three study periods, by clipping approximately 1 cm above the soil surface. Samples were dried at 70 °C to constant weight, and dry biomass was calculated per hectare.

For forage quality determinations, *L. tenuis* plants were clipped in December, January, and February, with similar results. The biomass quantity and quality required for acceptable calf performance were evaluated by Dry Matter (DM); Digestible Dry Matter (DDM) and Metabolisable Energy (ME) –by Tilley and Terry method-; Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) –by Van Soest *et al.* (1991) method-and Crude Protein (CP) -by Kjeldahl method- of promoted *L. tenuis* plants. All these parameters were evaluated following routinely protocols and processes standardized in the Animal Nutrition and Forage Evaluation Laboratory located in INTA Balcarce Experimental Station (Buenos Aires, Argentina).

Statistical analysis

Since the weaning treatment was applied directly to the cow and the calf, they were both considered as the experimental unit for all analyses. The experimental design was completely randomized and each study period represented an independent experiment with a different stock of animals. Plant biomass, WG, and DWG for EW and UW calves, and cow BCS were analyzed by *t*–Tests (P ≤ 0.05) for mean separations for each period using the INFOSTAT statistical software package (InfoStat version 2010. Grupo InfoStat, FCA, Universidad Nacional de Córdoba, Argentina, http://www.infostat.com.ar). P–values ≤ 0.05 were considered statistically significant and P > 0.05 but ≤ 0.10 were considered trends.

RESULTS

Biomass accumulation and nutritional values

For all three study periods, *L. tenuis* biomass accumulation was consistently higher than the semi–natural pas-

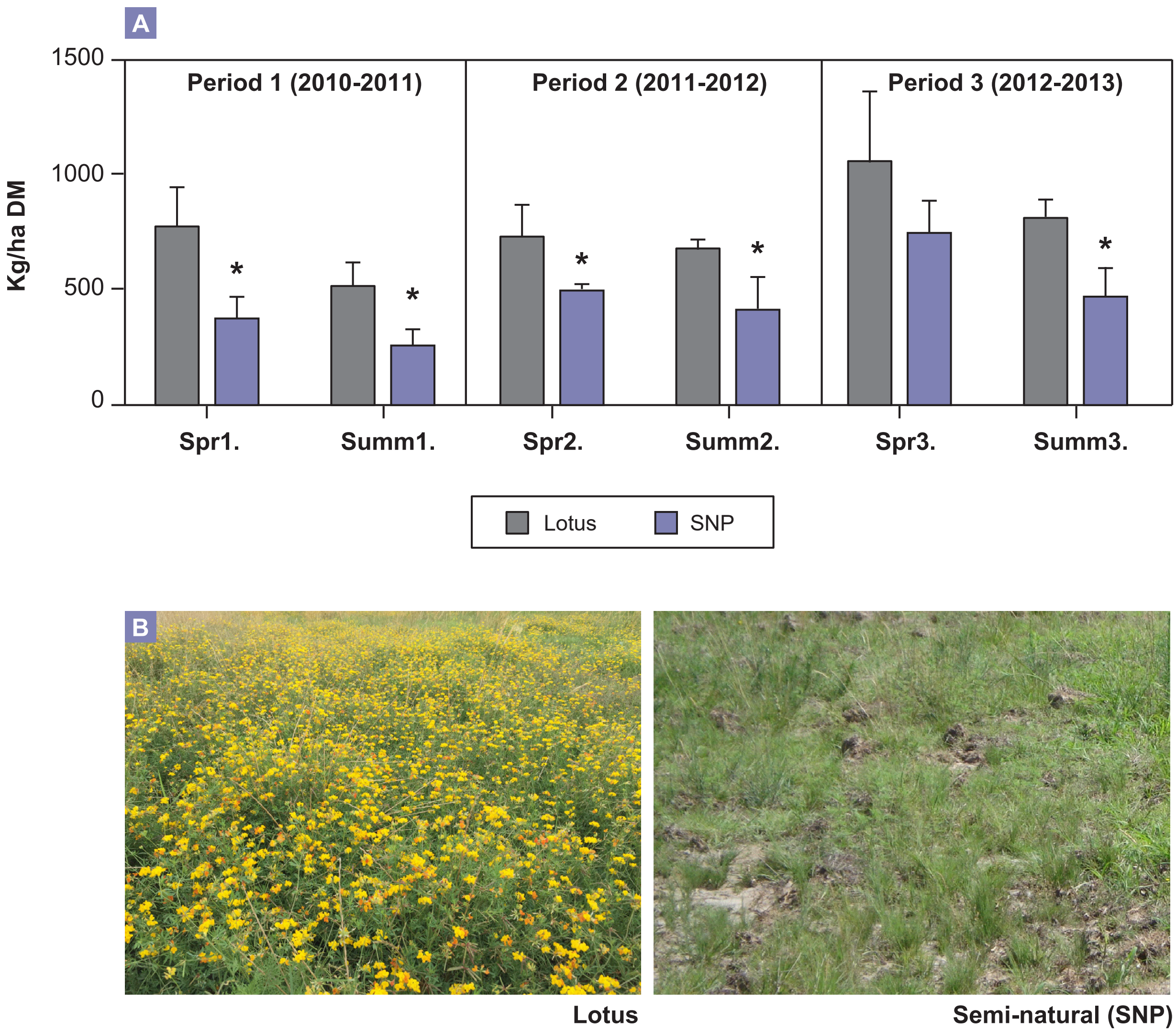

Figure 1 (A) Average value of forage dry mass accumulation (kg ha^{-1} DM) during Spring (Spr) and Summer (Summ) seasons during three years of experimental evaluation (period 1, 2 and 3), in promoted *L. tenuis* (Lotus), grey bars, and semi–natural pasture (SNP), violet bars. Bars (mean ± SD; n = 3) with asterisks represent significant differences between forage offer. (B) Typical observation of marginal soils after 4 to 5 yr. of *L. tenuis* promotion and semi-natural vegetation in marginal areas of the Salado River Basin.

ture biomass, with an average value per growth period of 4525 kg ha^{-1} DM and 2824 kg ha^{-1} DM, respectively (Figure not shown). Moreover, as shown in figure 1.A, during the summer season (January–February–March), biomass was lower in the semi–natural pasture, while *L. tenuis* biomass was slightly higher, and even more so compared to semi–natural pasture in the grazing months of EW calves (February–March). Figure 1.B shows the typical coverage that each pasture reached in the summer season.

In addition to biomass accumulation, table 1 shows the values of forage nutritional quality in promoted *L. tenuis* plants during the summer season.

Nutritional quality	Mean †	±	SD ‡
DM	245.3	±	20.7
CP	203.3	±	14.5
DDM	755.7	±	32.0
ME	2.73	±	1.2
NDF	299.0	±	31.1
ADF	252.3	±	30.8

Table 1. Forage nutritional quality of promoted *L. tenuis* evaluated as dry matter (DM, g kg^{-1}), digestible dry matter (DDM, g kg^{-1} DM), metabolizable energy (ME, Mcal kg^{-1} DM), neutral detergent fiber (NDF, g kg^{-1} DM), acid detergent fiber (ADF, g kg^{-1} DM), and crude protein (CP, g kg^{-1} DM).

† Values are averages from samples taken at three different times, from December to February. ‡ Standard deviation.

Influence of weaning treatment and promoted *L. tenuis* pasture on calf performance

Calf DWG was influenced by weaning treatment (table 2 A). DWG was higher during Study period 2 (2011–2012) (DWG = 0.65 kg day^{-1}P ≤ 0.05) and presented a trend in favor of EW and grazing on promoted *L. tenuis* during Study period 1 (2010–2011) (DWG = 1.21 kg day^{-1} P≤ 0.10). However, during Study Period 3 (2012–2013), there was a difference in favor of UW calves grazing on semi–natural pastures (DWG = 0.70 kg day^{-1} P ≤ 0.05). Regarding WG, it is important to note that all calves in both treatments weighed approximately the same (~160 kg) at the beginning of each study period (table 2 B). No WG differences were found between weaning treatments during Study period 2 and 3. However, there were WG differences during period 1 in favor of EW and grazing on promoted *L. tenuis* during 25 days.

	Period ‡	Item	Conventional-weaned†	Sd §	Early-weaned†	Sd §	*P-* value
A		**Daily weight gain (kg)**					
	1	**Final period**	1.106	0.29	1.21	0.22	0.10
	2	**Final period**	0.35	0.19	0.65	0.09	0.0025
	3	**Final period**	0.708	0.315	0.35	0.083	0.0023
B		**Weight (kg)**					
	1	**Initial**	160	6.07	164.1	12.47	0.155
		Final	187.65	9.82	194.45	13.63	0.028
		Period change	27.65		30.35		
	2	**Initial**	162.1	9.9	163.8	5.93	0.392
		Final	174.1	11.76	186	3.81	0.26
		Period change	12		22.2		
	3	**Initial**	154.23	14.14	156.63	17.48	0.288
		Final	196.77	25.18	177.94	20.72	0.15
		Period change	42.54		21.31		

Table 2. Influence of weaning treatments and grazing source on calf performance expressed as (A) Daily weight gain (kg) and (B) Weight (kg).

† Conventional–weaned treatment consisted of cow–calf pairs (n = 20 calves) grazing on semi–natural pastures while early–weaned treatment consisted of 4–5–month–old calves (n = 20) grazing on 2 hectares of promoted *L. tenuis* paddocks. ‡ Study period 1: (2010–2011) lasted 25 days, 2: (2011–2012) lasted 34 days and 3: (2012–2013) lasted 60 days. §Standard deviation.

Period†	Item	Conventional-weaned	Sd¶	Early-weaned	Sd¶	*P- value*
	BCS					
1	**Initial‡**	3.005	0.17	2.968	0.249	0.71
	Final§	3.085	0.12	3.421	0.334	0.0005
	Period change	0.08		0.453		
2	**Initial‡**	2.917	0.25	2.625	0.294	0.056
	Final§	2.833	0.25	2.9	0.241	0.37
	Period change	-0.084		0.275		
3	**Initial‡**	2.984	0.146	2.976	0.251	0.88
	Final§	3.083	0.14	3.433	0.323	0.023
	Period change	0.099		0.457		

Table 3. Influence of weaning treatments on cow performance expressed as Body Condition Score (BCS).

† Study period 1: (2010–2011) 25 days, 2: (2011–2012) 34 days and 3: (2012–2013) 60 days. ‡INITIAL BCS was measured in all cows at the beginning of both treatments (Conventional and Early weaning). § FINAL BCS was measured in all cows at the end of each Study period time. ¶ Standard deviation.

Influence of weaning treatment on cow performance

At the end of each assay, cow BCS (table 3) improved more in EW cows than in LC for Study Periods 1 and 3 (P< 0.05) but no differences were recorded for Study Period 2. It should be noted that in Study Period 2 EW cows started with a lower BCS (2.625) than LC (2.917). However, by the end of the 34–day treatment, BCS gain was 0.275 for EW cows but –0.084 for LC cows. At the same time, in all the three studied periods, the period change value was greater for the EW cows compared to the period change value for the CW cows.

DISCUSSION

The grasslands of the Flooding Pampa are subject to the combined effects of grazing, floods, and droughts. Thus, a sustainable solution is needed for forage production enhancement in marginal environments. *L. tenuis* promotion is an appealing alternative for cattle production in constrained environments in this region. Our results show that *L. tenuis* promotion produced higher forage yields than the supply provided by the semi–natural pasture under these soil conditions (figure 1A).

L. tenuis not only contributes with quantity but also nutritional quality (table 1). *L. tenuis* values are comparable to those of other two *Leguminosae*: *L. corniculatus* (L). and *T. repens* (L). (Peiretti *et al.*, 2016) with global commercial importance (Phelan *et al.*, 2015) rich in high-quality protein content and highly digestible (Kaplan *et al.*, 2009; Graves *et al.*, 2012).

This study shows a clear improvement in BCS for EW cows. Similar results have been reported in other weaning studies conducted on pasture (Merrill *et al.*, 2008; Martins *et al.*, 2012; Johnson *et al.*, 2015). The lower BCS of LC compared to EW cows may be explained mainly by the continued demand for milk by UW calves (Johnson *et al.*, 2015). Therefore, since UW calves are frequently maintained as cow–calf pair for approximately a month and a half longer than the period analyzed in this study, further BCS losses in LC would be expected. As reported by Whittier (1995), the long–term effect of lactation may delay pregnancy, so earlier weaning would improve BCS and increase pregnancy rate (Thrift and Thrift, 2004).

During Study Period 1, DWG did not differ between treatments and was higher than in Study Periods 2 and 3. In turn, differences were detected between treatments in the latter two periods, with higher DWG in EW than UW calves for Study Period 2, while the opposite occurred for Study Period 3. Such discrepancy could be given by the interval between days that the calves were found grazing *Lotus* in each study period. Hence, it would not be advisable to keep the calves grazing promoted *L. tenuis* for more than 34 days, probably due to the trampling effect generated by the calves on the pasture, unless the stocking density per hectare will be reduced. However, to draw better conclusions further research analyzing additional sources of variation is required.

Weatherly (2008) reports that EW calves aged 3–6 months require 160 g kg^{-1} DM of CP for a 0.70 kg day^{-1} growth rate. Former information and our results showing CP values of 203.3 g kg^{-1} DM and DM of 245.3 g kg^{-1} for promoted *L. tenuis* suggest that it is highly suitable as forage. In our study, this is reflected by the WG observed for animals grown on pastures promoted with predominance of *L. tenuis* during 25 days. The promotion of small areas of *L. tenuis* thus seems to be an important strategy enabling higher yields, taking into account that our results suggest that only 1 hectare is required to fully feed ten 4–5–month–old calves for a short period (table 2).

It is important to highlight that the promotion of *L. tenuis* would be one more link in the forage chain in a cow breeding enterprise, which would determine an advantage in a given period, which maybe be accompanied by other resources such as natural grassland or ryegrass promotions.

CONCLUSIONS

The technology of *L. tenuis* promotion that was designed and assayed by the Chacra Experimental Integrada de Chascomús produced higher yields than those provided by semi–natural pastures. Also, *L. tenuis* has an acceptable nutritional value for adequately feeding a considerable number of calves on a small surface. *L. tenuis* has a high capacity for natural reseeding and can withstand the water deficit that often occurs from late spring through summer (Vignolio *et al*., 2011; Escaray *et al*., 2012). Forage supply is especially important in summer when breeding herd requirements are usually at their maximum. Ideally, this demand should be met by pasture quantity and quality and/or supplementary feed. Another point to consider is that in grasses and legumes the digestion rate is influenced by the increase in the lignin content at the beginning of the flowering period (Mahyuddin, 2008). *L. tenuis,* however, continues vegetating even after the flowering period, with a wide overlap between vegetative and reproductive growth, as has been previously described for indeterminate growth species (Vignolio *et al*., 2016). Thus, EW of calves grazing on this forage is a useful management practice that reduces grazing pressure on semi–natural pastures, decreasing cow nutrient requirements. BCS improvement in EW cows could shorten the postpartum interval and improve pregnancy rate. This management practice can be potentially transferred to producers. Likewise, its adoption will allow us to increase the accuracy of the obtained results and its adaptation to other environments. It is also important to highlight the production of higher–quality meat, identifiable by its levels of unsaturated fatty acids, from animals fed on promoted *L. tenuis* compared to meat from animals fed in intensive fattening systems based on grains and balanced pelleted foods (Acosta *et al*., 2016). Therefore, we consider that this cow management practice could effectively improve the productivity in Argentina's most important livestock breeding region.

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