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Effects of Grazing on *Bituminaria bituminosa* (L) Stirton: A Potential Forage Crop in Mediterranean Grasslands

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With 3 figures and 2 tables

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Abstract

Plant traits of *Bituminaria bituminosa*, as affected by different intensities of cattle grazing, were studied in a Mediterranean grassland in Israel. *B. bituminosa* is a widespread Mediterranean perennial legume species that may potentially serve as a fodder crop in Mediterranean grasslands. The aims of the present study were: (i) to evaluate the responses of *B. bituminosa* to different cattle grazing intensities; (ii) to study functional traits associated with grazing tolerance; and (iii) to evaluate its potential as an alternative forage crop in the region. A total of 100 *B. bituminosa* plants were monitored in field conditions. During the growing season each individual was sampled five times and the following plant traits were monitored each time: (i) aboveground biomass production, (ii) plant height, (iii) specific leaf area (SLA), (iv) number of flowers, (v) seed mass and size, (vi) tannin concentration in leaves, (vii) total nitrogen in leaves, (viii) fibre concentration in leaves (Neutral Detergent Fiber), and (ix) *in vitro* dry matter digestibility. The results showed that grazing intensity and history of grazing affected *B. bituminosa* performance. Plant biomass, height, and flower and seed production were all reduced when plants were exposed to cattle grazing. However, under moderate grazing intensities, its plant cover remained relatively stable indicating a potential tolerance under this stocking rate. The nutritious characteristics of *B. bituminosa* leaves were good, and the condensed tannins concentration found indicated favourable conditions for digestion. Moreover, the *in vitro* digestibility studies indicated relatively high values (46–51 %) of digestion. *B. bituminosa* may be considered as a potential crop for cattle feeding in Mediterranean grasslands. Growing this plant in dense stands in rotational paddocks may provide alternative sources of natural fodder protein, reducing the potential costs of artificial feed supplements.

Key words: biomass — cattle — fodder — Israel — legumes — plant traits — *Psolarea*

Introduction

Domestic livestock grazing has influenced the economies and culture of Mediterranean ecosystems for > 7000 years (Noy-Meir and Seligman 1979, Edelstein and Milevsky 1994). This long history of grazing has been a major factor in determining the structure, organization and traits of the plant communities in these ecosystems (Noy-Meir et al. 1989, Seligman 1996). Selective herbivory can play a key role in structuring plant communities and can have important consequences for plant functional traits and ecosystem functioning (de Mazancourt et al. 1999). The long history of exposure to grazing has favoured species that have evolved functional traits that enable them to avoid defoliation or to cope with it through tolerance or resistance to grazing (Diaz et al. 2001, Abd El Moneim and Elias 2003).

Bituminaria (*Psolarea*) *bituminosa* (L) Stirton is a Mediterranean perennial legume, widely distributed in countries around the Mediterranean basin; it is traditionally used for feeding goats in the Canary Islands (Ventura et al. 2000), and is assumed to be tolerant of heavy grazing (Sternberg et al. 2000). It is known under several common names such as 'bitumen trefoil' (because of the strong smell of bitumen when the leaves are crushed) or 'tedera' in the Iberian Peninsula

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(Muñoz et al. 2000). It is characterized by secondary compounds in the mature leaves (Pistelli et al. 2003). The plant sprouts before the onset of the rains and grows till the end of the spring, attaining primary production double that of the common herbaceous species such as *Hordeum bulbosum* L. and *Avena sterilis* L. In winter and early spring, when more palatable species are available to the cattle, it is grazed only under heavy stocking rates, and it has been observed that cattle feed on *B. bituminosa* under moderate grazing pressures only in mid-spring, when the principal grasses become less palatable because of maturation and growth of spikes. In late spring, when the herbaceous species dry up and forage quality declines, *B. bituminosa* remains green and develops pods with large nutritious seeds, so that cattle intensively graze the whole plant. Consequently, it can become an important component of the cattle diet at the end of the green growing season (May). Despite this fact, preliminary data showed that its cover between years was not significantly reduced even under heavy cattle grazing pressure, when grazing was deferred at the beginning of the growing season (Sternberg et al. 2000).

As *B. bituminosa* is one of the ubiquitous perennial legume species in the region, the traits that confer the observed degree of tolerance to grazing on it are worth deeper study. Nevertheless, the presence of secondary metabolites that reduce palatability could also have deleterious effects on animal nutrition and health. Therefore, the evident advantages of the species as a forage crop may be compromised to a greater extent than has been realized. The present study was undertaken to obtain a better understanding of the role of this species as a forage resource in a heterogeneous rangeland vegetation.

The specific aims of the present study were: (i) to evaluate the responses of *B. bituminosa* to different cattle grazing intensities; (ii) to study functional traits associated with grazing tolerance; and (iii) to evaluate the potential of this plant as an alternative native forage crop.

Materials and Methods

The experiment was conducted at the Karei Deshe Experimental Farm, located in the north-eastern part of Israel (32°55′N,35°35′E, altitude 150 m a.s.l). The topography is hilly, with slopes generally <10 %. Soils are brown basaltic protogrumosols. The site has a Mediterranean climate, characterized by wet and mild winters with mean minimum and maximum temperatures of 7 and 14 °C, respectively. The average seasonal rainfall is 570 mm, falling mostly in winter. The rainfall season covered by the present study (2002/2003) was relatively wet, with 754 mm of precipitation. Germination of annuals and regrowth of most perennials happens soon after the first rains. Growth is rather slow during the winter months December–January, but the vegetation is usually well established by mid- to late-January. Growth is rapid in the spring, and peak growth, coinciding with seed set, occurs in March–April. By mid-May, most of the herbaceous vegetation is dry and most seeds have been dispersed, so that the forage quality declines at the beginning of the long, dry summer.

Grazing treatments comprised two stocking rates. Each grazing treatment was allocated to one paddock in a randomized block design with two replicates per treatment. The stocking rates were 0.55 and 1.1 cow ha^{-1} $year^{-1}$, designated M (moderate) and H (heavy), respectively. The grazing season commenced soon after the green standing herbaceous biomass exceeded 500 kg dry matter (DM) ha^{-1}, generally by mid-January each year, and ended towards the end of the summer in September–October (for full details of the experimental design see Sternberg et al. 2000).

In the autumn of 2002, before the beginning of the growing season, 20 individual *B. bituminosa* plants in each paddock were marked with colour plastic tags. Individual plants were paired according to their proximity to one another (mean distance: 1.5 m). Plant selection was based on the knowledge that similarity in the dry structures left from previous growing seasons indicated approximately similar growing conditions and age. One member of each pair was protected from grazing (ungrazed – U) and the other was exposed to grazing (grazed – G). In each paddock 10 plants were protected from grazing by metal cages ($110 \times 110 \times 110$ cm), covered with a mesh of chicken wire. No light reduction was observed beneath the cages. In addition, 10 individuals were marked in each of two paddocks that had not been grazed for the previous 30 years. A total of 100 *B. bituminosa* plants were monitored in this study, divided among five treatments with two replications each: (1) ungrazed control (C); (2 and 3) protected and unprotected plants in the moderately grazed paddocks (MU, MG, respectively); 4 and 5) protected and unprotected plants in the heavily grazed paddocks (HU, HG, respectively).

Each individual was sampled five times during the growing season: (1) early winter (January), before the start of grazing; (2) winter (February), a month after the start of grazing; (3) early spring (March), 2 months after the start of grazing; (4) spring (April), beginning of the flowering stage of *B. bituminosa*; and (5) late spring (May), at seed set.

In each sampling event the following plant traits were monitored: (i) above-ground biomass production; (ii) plant height; (iii) specific leaf area (leaf area/leaf dry mass – cm^2 g^{-1}); (iv) number of flowers; (v) seed mass and size; (vi) tannin concentration in leaves; (vii) total nitrogen in leaves;

(viii) fibre concentration in leaves (NDF, Neutral Detergent Fiber); and (ix) *in vitro* dry matter digestibility. Plant traits were measured from protected and unprotected plants.

Plant biomass production was measured by indirect and direct procedures. Indirect techniques included the use of allometric equations that were applied to all individuals. The variables included:

1 Plant height, defined as the maximum vertical distance from the ground level to the highest point of the plant.
2 Crown diameter or crown width is the mean of the maximum horizontal dimension and the horizontal dimension measured perpendicularly to the maximum one.
3 Crown volume was determined for each individual by using the formula for the solid upper half spheroid that appeared to give the best fit to the natural shape of the crown (Sternberg and Shoshany 2001):

$$\text{Crown volume} = (4/3) \times \pi \times r^2 \times h$$

in which r is the horizontal radius and h is the plant height.

Each sampling event included direct biomass measurements on five *B. bituminosa* plants adjacent to the targeted plants (both grazed and ungrazed plants) in each paddock; their crown volume was correlated with their respective dried weights. Through this procedure we estimated the above-ground biomass production, and the resulting estimates were finally tested at the final sampling (in May), when all the targeted plants were harvested. The harvested plants were brought to the laboratory and dried in an oven at 75 °C for 3 days, after which all above-ground structures (stems and leaves) were weighed at room temperature on an electronic balance to the nearest 0.01 g.

Plant height was defined as the vertical distance from the ground level to the highest point of the plant. The number of inflorescences, number of flowers per inflorescence and number of seeds per flower in each plant were measured in the last two sampling events (April–May). The seed mass on each plant was obtained by weighing 20 randomly selected seeds on an electronic balance to the nearest 0.001 g. The sizes of the weighed seeds were determined by measuring them with a calibre (150 × 0.02 mm).

Measurements of SLA were conducted on three replicate leaves (each of which comprised three leaflets) per plant on each sampling date. The leaves were severed from the plant, rapidly wrapped in moist paper, placed in plastic bags and stored in a cool box pending further processing in the laboratory, approximately 4–5 h after field collection. In the laboratory, the samples were placed in bags with deionised water and stored in a dark cold room at 5 °C for at least 12 h. This procedure ensured full rehydration of leaves to enable determination of the water-saturated values of SLA (Cornelissen et al. 2003). The following morning the leaf blades were weighed to determine their fresh weights, and immediately scanned to determine their projected areas. The samples were then oven-dried at 65 °C for 2 days, and their dry mass was determined (Garnier et al. 2001).

Mature, undamaged leaves were collected during each sampling event, for determination of condensed tannins, total nitrogen and NDF; in plants collected at the end of the experiment (May), nitrogen and NDF were measured in the shoots also. Condensed tannins in plant extracts were determined according to the butanol–HCL procedure (FAO/IAEA 2000). Nitrogen concentration in dried and ground (2-mm mesh) leaves and shoots was obtained separately by the Kjeldahl digestion methodology with a Kjeltech 1035/38 Auto Analyser (Tecator, Hoganas, Sweden). Neutral detergent fibre (NDF or 'fibre'), which indicates the total amount of cell-wall material, was determined according to Goering and van Soest (1970) with a Fibertec System M1020 Hot Extractor (Tecator).

In vitro DM digestibility was determined on leaves from plants collected at the end of the growing season, in May. These plants had not been defoliated during the growing season in order to prevent confounding effects on plant performance. All leaf samples were ground in a Wiley mill (Arthur H. Thomas, Philadelphia, PA, USA) to pass a 2-mm mesh-size screen. *In vitro* DM digestibility was determined according to Tilly and Terry (1963). The donor animals, two Merino rams, were fitted with a ruminal cannula (inner diameter 10 cm). The rams were maintained on a diet sufficient for their maintenance; it contained a 50 : 50 mixture of chopped alfalfa hay and grain (16 % CP, 29.1 % NDF, and 1.6 Mcal NE_L on a DM basis, Mixture 1471®, Matmor Ltd, Ashdod, Israel). The daily meal was offered every 2 h by automatic feeders to ensure steady-state conditions in the rumen.

Analysis of variance (ANOVA) was applied to the data obtained from the experimental blocks on the various sampling dates. Nested ANOVA was used to evaluate the effects of protection from grazing (cages) within each grazing treatment (grazed vs. ungrazed). Data on plant biomass and SLA were log transformed, while those on the numbers of inflorescences, flowers per inflorescence, and seeds per inflorescence and plant were square-root transformed (Sokal and Rohlf 1995). The seasonal growth data were subjected to the repeated measures ANOVA by means of the JMP 5.01 software (SAS Institute Inc., Cary, NC, USA) to estimate the overall significance of treatment effects. Factors examined in the model were: block, treatment and month (sampling date), and their interactions.

Results

The effects of grazing on above-ground biomass are presented in Fig. 1a. Plant biomass accumulation differed significantly among treatments during the growing season (Table 1): the biomass in the Control – C-, Moderate – MU- and Heavy – HU-grazing treatment increased steadily during the growing season, whereas that in the heavily grazed (HG) treatment, remained significantly lower (Fig. 1a). Significant differences in biomass were evident at the first sampling event (January): plants

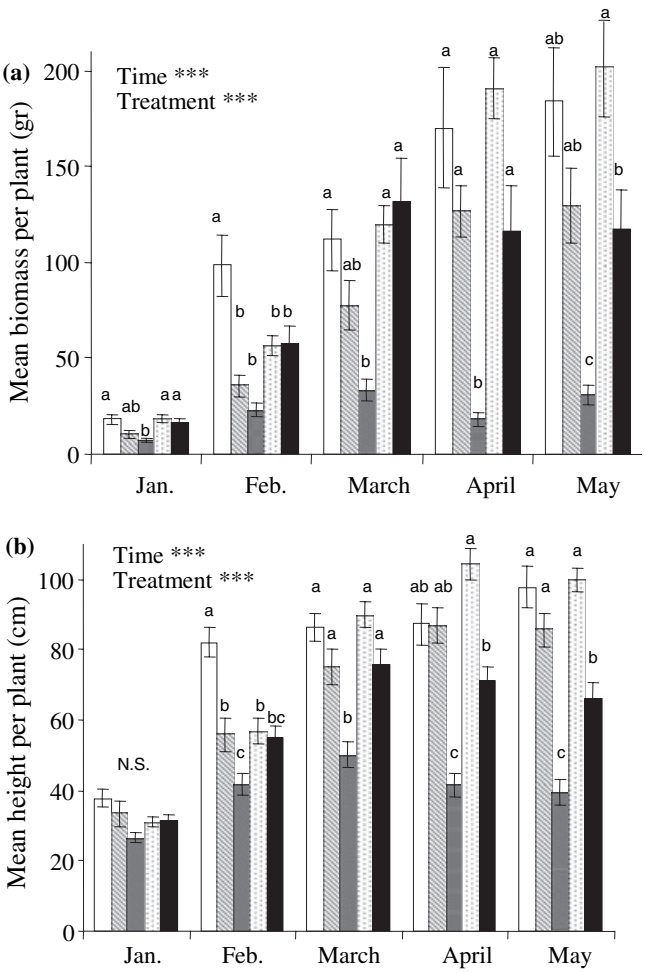

Fig. 1: Effects of grazing treatments on plant biomass (a) and height (b) of *B. bituminosa* during the growing season. Treatments: control (plain white), moderate ungrazed (MU – thin hatching), moderate grazed (MG – thick hatching), heavy ungrazed (HU – black dots), heavy grazed (HG – full black). Means marked with the same letter do not differ significantly according to Tukey's HSD tests at $P < 0.05$

in the heavily grazed treatments (HU and HG) were smaller than those in the moderately grazed ones (MU and MG). These differences were not evident in the following sampling (February), when only the control plants (C) showed higher biomass. From March until May, biomass differences between heavily grazed plants (HG) and those in the remaining treatments became significantly greater. In May, significant differences were also noted between the protected and the grazed plants under moderate grazing pressure (Fig. 1a). However, at the end of the growing season no significant differences were noted among the non-grazed treatments (C, MU and HU), irrespective of their history of grazing exposure.

Similar trends were noted for plant height (Fig. 1b). Plants in the heavily grazed treatment (HG), were significantly shorter than those protected from grazing. This trend continued throughout the growing season. In April and May plants under moderate grazing pressure were also significantly shorter than protected individuals, but remained significantly taller than the heavily grazed ones (MG vs. HG; Fig. 1b). As with biomass, no significant differences in height were noted among ungrazed treatments (C, MU and HU) at the end of the growing season. Surprisingly, plants were able to recover fast from grazing probably through the reallocation of root resources into shoot growth.

The effects of grazing on the number of inflorescences in *B. bituminosa* were considered from March to May. There was a significant reduction in the number of inflorescences with increasing grazing pressure and exposure (Fig. 2a, Tables 1 and 2), and the differences increased in the course of the growing season. There were no differences among the protected plants in the various treatments, in their numbers of inflorescences.

The number of flowers per inflorescence was relatively uniform, ranging from 13 to 17, and was not affected by grazing pressure, exposure or history of grazing. However, the number of seeds per plant was significantly reduced with increasing grazing intensity and when there was a history of exposure (Fig. 2b). The numbers of seeds on plants exposed to grazing were four and five times smaller than the numbers on those protected from grazing at similar grazing pressure (MU vs. MG and HU vs. HG, respectively). Seed production was significantly higher in paddocks that had not been grazed for 30 year (control – C; Fig. 2b). The number of seeds per inflorescence was significantly smaller in heavily grazed plants than in those in the remaining treatments: 0.59 seeds per inflorescence in HG vs. 2.6 and 1.8 in HU and C, respectively (Fig. 2c, Table 2).

Seed mass was not affected by grazing treatments and the weights of individual seeds ranged from 48 to 55 mg (Table 2). Nevertheless, seeds from moderately grazed protected plants (MU) where significantly longer than those from the remaining treatments: 0.95 compared with 0.74–0.83 cm (Table 2).

Specific leaf area was not affected by grazing treatments, but significant decreases in SLA were observed in the course of the growing season (Tables 1 and 2). The mean SLA over all treatments ranged from 156.2 $cm^2\ g^{-1}$ in February to 109.9 $cm^2\ g^{-1}$ in May.

Table 1: Results (F-values) of two-way and repeated measures ANOVA for functional traits of *B. bituminosa* in different treatments and comparison between protected and grazed plants

	Biomass		Height		Inflo. per plant		SLA		Condensed tannins		Nitrogen	
	F	P	F	P	F	P	F	P	F	P	F	P
Time	**51.6**	**< 0.0001**	**143.0**	**< 0.0001**	**36.2**	**< 0.0001**	**36.1**	**< 0.0001**	**13.1**	**< 0.0001**	**271.1**	**< 0.0001**
Block	0.55	0.46	0.19	0.66	0.12	0.73	0.62	0.43	0.44	0.51	0.67	0.42
Treatment	**8.5**	**< 0.0001**	**9.36**	**< 0.0001**	**10.8**	**< 0.0001**	0.92	0.43	0.55	0.65	**3.98**	**0.022**
Grazed vs. ungrazed	**21.7**	**< 0.0001**	**73.9**	**< 0.0001**	–	–	0.26	0.61	**5.46**	**0.02**	–	–

Bold numbers indicate significant differences. To avoid congestion of the table results for interactions are not included, as they were not significant.

B. bituminosa plants showed no significant change in condensed tannins (CT) production in leaves as a result of the grazing treatments, but the CT concentration decreased significantly as the plants developed (Table 1) The CT concentrations ranged from 2.4 % in February to 1.6 % in May, being significantly higher in grazed vs. ungrazed plants (Table 1).

Nitrogen concentration in leaves significantly decreased with increasing plant growth in the course of the growing season (Fig. 3a), and there were important differences among the grazing treatments, with plants exposed to grazing generally showing higher values. These differences were particularly evident in April, when leaves of heavily grazed plants (HG treatment) had significantly higher N concentrations than ungrazed plants (Fig. 3a). The nitrogen level in shoots (measured in May only) was lower than that leaves (0.6% vs. 2.2 %) and showed no significant differences among treatments (Table 2).

The NDF content in leaves was significantly lower in control plants (C) that had not been exposed to grazing for a long period than in previously grazed plants. This was true for those plants that were protected from grazing in the present study (MU and HU, Fig. 3b) and for those that were continuously grazed, irrespective of their grazing intensity. There were no significant difference in NDF among the shoots in the various treatments (Table 2). *In vitro* digestibility of leaves was negatively correlated with the NDF content: significant higher values of digestibility were observed in control plants, which gave up to 50 % absorption (Fig. 3c).

Discussion

The above-ground biomass of ungrazed *B. bituminosa* plants increased gradually during the course of the growing season, and until the peak of the herbaceous growing season (April). This was also true for plants exposed to moderate grazing pressure (MG). Only at the end of spring (May), when most of the annual vegetation starts to dry up, did differences become evident between protected plants and those under moderate grazing pressure (MU vs. MG, Fig. 1a). However, under high grazing pressure, *B. bituminosa* was continuously being eaten by the cattle, so that the residual biomass was constantly low. This finding confirms previous observations that cattle kept under heavy stocking rates graze this plant throughout the season (Gutman et al. 2000). It seems that a previous history of grazing exposure had an effect on current biomass production, as plants protected from grazing at heavy stocking rates were smaller than those protected from moderate grazing [mean dry weights (DWs) per plant of 110 and 200 g, respectively; Fig. 1a]. Despite this obviously expected result (i.e. that grazed plants are smaller), no previous data on this species were available for comparison with this finding. Similar results have been reported for other grassland species, in which defoliation negatively affected above-ground biomass production, and ungrazed plants showed higher biomass than grazed ones (Ferraro and Oesterheld 2002, Taddese et al. 2002). Nevertheless, it seems that under moderate grazing intensities *B. bituminosa* was able to compensate for biomass loss, probably through re-allocation of resources from the roots (Belsky 1986, Preston 1999) as no significant biomass differences between grazed and ungrazed plants were observed until April.

The proportionate loss of biomass was correlated with the difference in grazing pressure between treatments. Overall, plants under moderate grazing pressure (MG; 0.55 cow ha^{-1} $year^{-1}$) lost

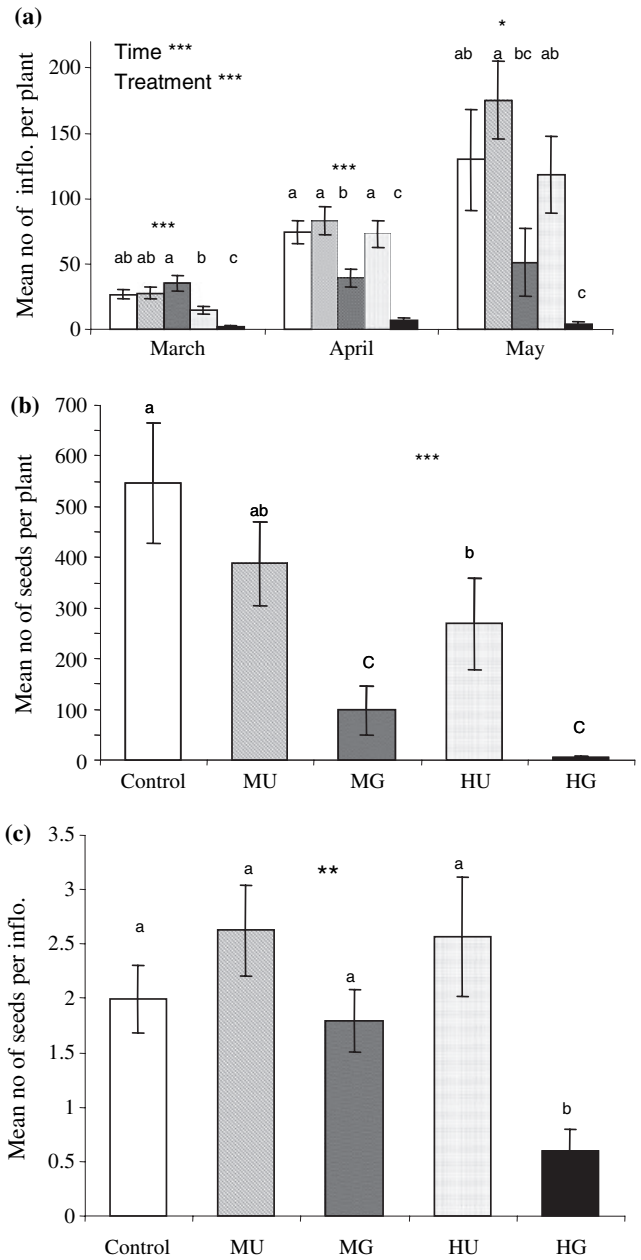

Fig. 2: Effects of grazing treatments on reproductive structures. Changes in number of inflorescences per plant (a), seed production per plant (b), and number of seeds per inflorescence (c). Treatment identification as in Fig. 1. Means marked with the same letter do not differ significantly according to Tukey's HSD tests at $P < 0.05$)

approximately 30 % of their above-ground biomass to grazing, while under heavy grazing (HG, 1.1 cow ha^{-1} $year^{-1}$) about 65 % was eaten. Similar proportionate reductions were observed in plant height: moderately and heavily grazed plants were 30 % and 50 %, respectively, shorter than protected ones.

Table 2: Results (F-values) of two-way ANOVAs for functional traits of *B. bituminosa* in different treatments and comparison between protected and grazed plants

	No. flowers per inflor.		No. seeds per plant		No. seeds/ per inflor.		Seed mass		Seed length		N in shoots		NDF		Digesti-bility		N (April)		SLA (May)	
	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
Block	2.81	0.1	**25.2**	**< 0.001**	2.66	0.11	**4.7**	**0.03**	**28.8**	**< 0.001**	0.21	0.65	0.006	0.93	–	–	**5.3**	**0.02**	3.09	0.08
Treat.	2.28	0.09	**16.2**	**< 0.001**	**5.42**	**0.002**	2.52	0.057	**37.9**	**< 0.001**	0.23	0.8	**20.3**	**< 0.001**	**5.5**	**0.006**	**5.7**	**0.001**	**4.06**	**0.009**
Grazed vs. ungrazed	0.01	0.92	**26.7**	**< 0.001**	**22.5**	**< 0.001**	0.002	0.99	**4.12**	**0.04**	1.02	0.32	**5.41**	**0.02**			**38.2**	**< 0.001**	0.006	0.98

Bold numbers indicate significant differences in growing time and between treatments. To avoid congestion of the table, results for interactions were not included, as no significant differences were found.

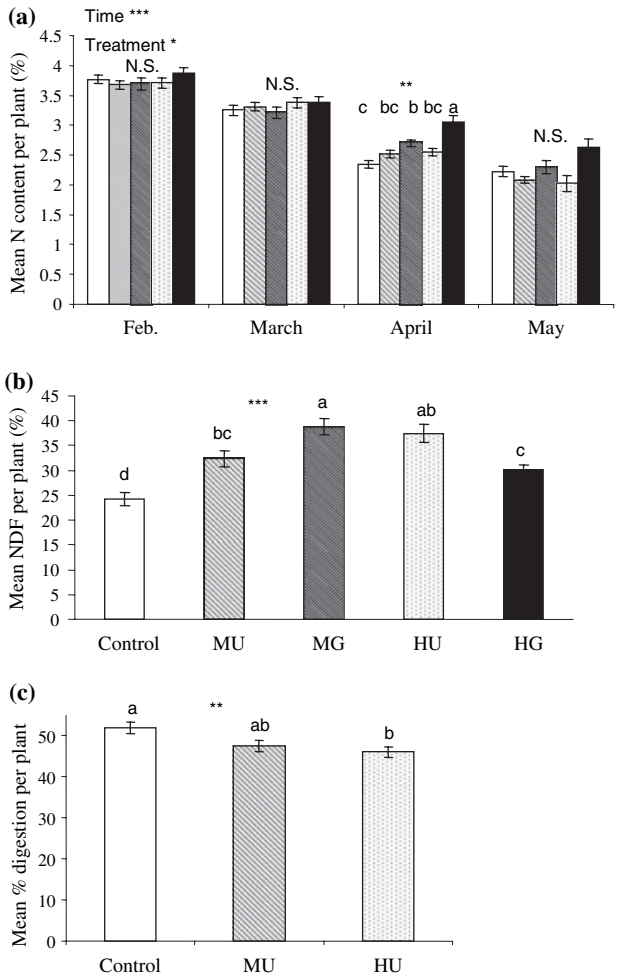

Fig. 3: Effects of grazing treatments on leaf traits. Mean N content (a), fibre content – NDF (b), and *in vitro* DM digestibility (c). Treatment identification as in Fig. 1. Means marked with the same letter do not differ significantly according to Tukey's HSD tests at $P < 0.05$

There was no significant influence of grazing on SLA. This was in accordance with the results obtained by Diaz et al. (2001), who found that SLA was not a good indicator of grazing response in this species. It is likely that abiotic factors such as soil nutrients or temperature had more effect than grazing on this parameter (Wilson et al. 1999).

Grazing had significant negative effects on reproductive structures. Flower and seed production were significantly lower under grazing, and their reductions correlated with grazing intensity (Sternberg et al. 2003). Cattle feed on inflorescences and seeds, as these may provide high protein contents. During seed set most of the annual vegetation has already dried, so that the reproductive structures of *B. bituminosa* are of higher quality than the surrounding herbaceous vegetation, and the small numbers of seeds of this species found in the soil seed bank [despite the large numbers −550 to 400 seeds per plant – produced under protection (Fig. 2b)], may indicate that they were heavily consumed by the cattle (Sternberg et al. 2003).

Among the protected plants, significant differences were found between treatments. The smaller number of seeds observed in the heavy grazing treatment indicated that plants were not able fully to compensate for previous years of defoliation (Warner and Cushman 2002).

The present results clearly show that increasing grazing intensity and a history of previous grazing affected *B. bituminosa* performance. Plant biomass, height, and flower and seed production were all reduced when this plant was exposed to cattle grazing. Moreover, under moderate grazing intensities (MG), the plant cover remained relatively stable, indicating that it is potentially tolerant of grazing under these stocking rates (Sternberg et al. 2000, Sternberg unpublished data).

Since *B. bituminosa* produces leaves early in the growing season and before the beginning of germination, the protein content of new leaves may provide a good nitrogen source for herbivores during this period (early autumn). This is also true at the end of the growing season, as this species remains green until late spring, when most of the herbaceous vegetation has already dried up and their fodder quality is diminishing. The nutrition characteristics of *B. bituminosa* leaves can be compared with those of low-quality alfalfa (*Medicago sativa* L.; Mathis et al. 2001). Moreover, the condensed tannins concentration found in the leaves indicates that they are suitable for digestion (Aerts et al. 1999) and contradicts previous findings that they contained higher concentrations of tannins, levels typical of non-palatable species (Ayers et al. 1997, Barroso et al. 2001).

Moreover, the present *in vitro* digestibility studies indicated much higher values (46–51 %) of digestion than those of the most dominant species of the Mediterranean shrubland, of which the digestibility ranged between 30 and 45 % (Perevolotsky 1994) However, Ventura et al. (2004) found higher values of dry matter digestibility (68 %) for *B. bituminosa*, which is used as an endemic forage shrub in Spain, and tannins contents of 1–2 % of dry matter, similar to the findings of the present study, and with similar values of NDF concentration. In the present study, we did not measure the lignin content and those of other components such as

oxalates, which adversely affect the DM digestibility of some forage shrubs such as *Rumex lunaria* L. and *Acacia salicina* Lindl. (Rodrigues et al. 1985, Ventura et al. 2004). Thus, the lower DM digestibility of *B. bituminosa* could be accounted for by possible differences in climate, soil and growth conditions, which might affect the chemical components and growth rate of the plants.

Considering the above, and the fact that each plant is capable of producing around 200 g of DW (equivalent to 2 t ha^{-1} at high planting densities), *B. bituminosa* may be considered as a potential crop for cattle feeding in Mediterranean grasslands, particularly if we consider two further characteristics: (i) it sprouts before the onset of the rains, and so provides fresh and green leaves before the availability of annual herbaceous pasture; and (ii) it provides green structures at the end of the growing season, when most of the herbaceous vegetation has already dried up. Growing this plant in dense stands in rotational paddocks, grazed only for short periods in early autumn and late spring, may provide alternative sources of natural fodder protein, and so reduce the costs of artificial supplemented food. This possibility would justify further studies aimed at evaluating cattle responses (e.g. to components of other secondary compounds not considered in the present study) and the economic viability of such a programme.

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