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The potential for using goats to control *Genista scorpius* shrubs in European black pine stands

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Abstract

The depopulation of mountain areas, and with it the reduction of livestock that traditionally grazed on the spontaneous vegetation in these areas, has led to an uncontrolled development of bushes and, consequently, a significant increase in fuel material and fire risk. In the Mediterranean basin, *Genista scorpius* (L.) DC. is of particular interest due to its invasive nature and ignition capacity. In this respect, the value of using goats for the control of *G. scorpius*, according to grazing season and stocking density, was studied while taking into consideration the morphological alterations, regrowth, surviving and flowering rates of bushes growing on a European black pine (*Pinus nigra* Arn. subsp. *nigra*) revegetated slope of the Pyrenees (Spain).

Goat grazing clearly affected *G. scorpius*' performance. While stocking density showed an effect on morphological modifications, the plant was much affected by the time of grazing. *G. scorpius* bushes in grazed areas, both in spring and autumn, showed a mean survival and regrowth rate (69% and 49%, respectively), intermediate but significantly different from that of bushes consumed only in autumn (58% and 32%) or in spring (93% and 65%), which did not differ from the non-eaten ones (100% and 66%). This suggests that the timing of herbivory in relation to *G. scorpius*' phenological stage is the most important factor affecting both, the survival and regrowth rates. Grazing also has an effect on flowering performance the next spring, since the flowering rate decreased from 38.5% in the non-grazed areas to 2.6% in the grazing ones. *G. scorpius* response to browsing appears to be associated with the section of twigs consumed, suggesting that this parameter could be used as an index of the level of impact on the bushes. While thorns have shown themselves to be efficient enough against most mammalian herbivores, browsing ability displayed by goats and the different response of *G. scorpius* depending on its phenological stage suggest that autumn is the most adequate season for this bush control and that efficiency increases with stocking density.

Keywords: Shrub control; *Genista scorpius*; Goats; Grazing season; Stocking density; Phenological stage

1. Introduction

The depopulation of mountain areas in the last years has led to a drastic reduction of livestock that grazed on the spontaneous vegetation growing

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in these areas. The abandonment of traditional agricultural activities has resulted in an uncontrolled development of bushes and, consequently, a significant increase of fuel material and of fire risk in forestry areas as well as a parallel loss of landscape quality in a territory with an important tourist industry. Previous attempts at bush control in different habitats, either by mechanical procedures or by fire clearing, have frequently been found to be unsatisfactory (Fernández Santos et al., 1992; Currás et al., 1995) or economically or physically inadequate. As an alternative to these ecologically aggressive techniques, the use of grazing herbivores could effectively control these areas (Tsiouvaras et al., 1989; Magadlela et al., 1995).

Within this context, *Genista scorpius* (L.) DC. is of particular interest due to its invasive and ignition capacity (Papió and Trabaud, 1991). *G. scorpius* can be found in the Mediterranean basin and particularly in areas of a basic substrate in Spain. This very ramified leguminous bush can reach 1.5 m high and is armed with strong and very acute lateral thorns which provide the bush with an efficient defence system against herbivores. In fact, it seems that sheep are only able to consume some flowers and fruit in spring while leaving untouched the rest of the bush's aerial parts (Ascaso et al., 1996). However, no information is available on *G. scorpius*' response to browsing, but previous studies on grazing behaviour in forestry areas (Torrano et al., 1995) indicate that goats devote a 36% of their total grazing time consuming this shrub, which suggests that this livestock species may well provide a potential alternative for its control.

Susceptibility of various bush species to browsing intensity seems to be species-related (Schmutz, 1983; Tsiouvaras et al., 1986). Grazing season, however, seems to be more important than intensity on the responses induced by defoliation (Whitham et al., 1991; Danell et al., 1994). In this respect, information is lacking on *G. scorpius*' responses to time of grazing or intensity of utilisation.

In this work, goats' potentiality for the control of *G. scorpius* bushes depending on grazing season and stocking density was evaluated from the perspective of morphological alterations (volume, number and length of new shoots), regrowth, survival and flowering rates after bush utilisation.

2. Materials and methods

The study was carried out on a south-facing European black pine (*Pinus nigra* Arnold subsp. *nigra*) revegetated slope of the Pyrenees in La Garcipollera Valley, Huesca, Spain (42° 38′N, 0° 30′W) at 920 m asl. The area was classified as Phytoclimatic Macrotype VI (Allue Andrade, 1990) where a sub-continental cold deciduous broad-leaved forest could potentially be developed. The mean annual temperature in the study area is 10.9°C with a range of the minimum and maximum mean from −7.8°C (January) to 34.1°C (July) and an average annual precipitation of 1019 mm ($n = 10$ years). The area was reforested 30 years ago with *P. nigra* (1400 trees/ha) showing at present an average of ca. 6 m height and 20 cm diameter at breast height (DBH). The actual understory vegetation showed a 37% evenly distributed bush cover, *G. scorpius* (L.) DC. and *Buxus sempervirens* L. being the most frequent species. The herbaceous layer was dominated by perennial grasses which include *Brachypodium pinnatum*, *B. retusum* and *Festuca arundinacea*. Graminoids (*Aphyllanthes monspeliensis*, *Carex hallerana*, etc.) and forbs (*Catananche caerulea*, *Thalictrum tuberosum*, etc.) were found at low frequencies.

An area of 1.8 ha. was fenced (1.8 m high) and divided into two identical areas to evaluate the effect of two stocking densities (9 vs. 18 goats/ha) on vegetation. Inside fences were used to divide each experimental area in three subareas, to be able to evaluate independently the spring (S), autumn (A) or both (S + A) grazing season effects on vegetation for the established stocking densities.

By the end of May (when *G. scorpius* was at full flower), two groups of adult and dry Blanca Celtibérica goats were allowed to graze for six week in S and S + A areas. On October 1, the same animals were transferred to the A and S + A areas where they remained for another six week. A third area (35 × 15 m), next to the grazing ones, was also fenced to prevent wild deer getting in, and was maintained as a control plot without grazing (NG).

3. Measurements

In order to evaluate the morphological effects of herbivory on *G. scorpius*, measurements of the

maximum height (h), longitudinal (D) and transverse (d) diameters of every individual plant were taken within three fixed transects ($10 \times 1\ m^2$) per subarea at the beginning and end of each grazing season. Twig section consumed was estimated by measuring the diameter of the six thickest twigs eaten (Valderrábano et al., 1996) on every plant within each fixed transect (ca. 10 plants/transect) of every treatment. The number of new shoots/twig and their length were measured on five plants chosen at random in each treatment one year after grazing. The number of new shoots were also expressed relative to the length of the twig on which they were growing, and this was used as a parameter to evaluate the browsing effect on plant compactness.

The effect of herbivory on survival and vegetative regrowth was evaluated 12 months following goats' utilisation on five strip areas, defined by two consecutive rows of pines, which represented a 50% of the surface area of each treatment (ca. 600 plants/subarea) and 100% of the reference one. Survival rate was estimated from the total number of living plants, those neither showing any green part nor regrowth being counted as dead ones. Regrowth rate was calculated as the average current annual growth expressed as the percentage of plant surface area covered by new shoots.

The effect of herbivory on *G. scorpius* flowering was evaluated, in the following spring, from the number of plants with flowers vs. number of living plants, as well as from the number of flowers/plant in each treatment. The number of flowers/plant in non-consumed plants was established from the number of flowers counted on a 25% volume of eight different size plants.

4. Statistical analysis

Data were analysed by a factorial-nested model, in which stocking density (9 and 18 goats/ha) and grazing season (S, S + A, A) were nested to grazing effect (grazed or non-grazed). The percentage of survival, regrowth and flowering were arcsin transformed but they have been plotted and discussed in actual percentages.

5. Results

5.1. Morphological modifications

5.1.1. Volume

To evaluate the direct effects of grazing on the plant, volume ($x = \pi Ddh/4$) at initiation and end of each grazing season was examined. While mean volume of non-eaten *G. scorpius* plants increased 20.5% in one year, plants within grazing areas showed a 44.6% reduction of their initial volume. Plants consumed both, in autumn and spring showed a mean volume reduction (45.3%) intermediate to, but significantly different ($p < 0.001$) from, that observed only in autumn (57.5%) or in spring (31.0%) grazing (Table 1). Mean volume of browsed bushes also showed a significant reduction ($p < 0.001$) with stocking density (35.9% vs. 53.3%). A significant interaction ($p < 0.001$) stocking density × grazing season was also detected showing that the effect of season on plant size was more pronounced at high, than at low stocking density.

5.1.2. Number of shoots

The response of *G. scorpius* to browsing was also brought forward by a significant reduction ($p < 0.001$) in the mean number of new shoots (6.2) counted the following spring with respect to that recorded on non-consumed bushes (15.2). The mean number of new shoots (Table 1) significantly decreased ($p < 0.001$) from spring to autumn grazing (7.7 vs. 4.6), being intermediate (6.2) for those bushes consumed during both the seasons. No significant effect of stocking density on the number of new shoots was detected. However, when these values were expressed as number of shoots per cm twig, higher ratios ($p < 0.001$) were recorded for spring than for the other treatments (NG, A and S + A), thus showing that spring grazing had a clear effect on plant compactness.

5.1.3. Shoots length

New shoots length (Table 1) measured on autumn grazed plants was significantly ($p < 0.05$) longer than that measured on either NG or S plants that did not differ significantly between them. Thus, average shoot length per plant seems to decrease with the number of new shoots as suggested by the negative correlation found ($r = -0.52^{**}$) between these two parameters.

Table 1
Effect of stocking density (SD) and grazing season (GS) on morphological alterations and twig section consumption in *Genista scorpius*

	Stocking density			Grazing season			rsd[e]	df[f]	Level of significance	
	NG[a]	low	high	S[b]	S + A[c]	A[d]			SD	GS
Volume change (%)	20.5aA	−35.9b	−53.3c	−31.0B	−45.3C	−57.5D	*25.09*	*202*	***	***
Section (mm)	—	2.1b	2.6a	1.8C	2.5B	2.8A	*0.59*	*118*	***	***
No. new shoots	15.2aA	6.8b	5.6b	7.7B	6.2BC	4.6C	*2.61*	*28*	NS	*
No. shoots/cm	1.1aB	1.1a	1.1a	1.5A	0.9B	0.7B	*0.31*	*28*	NS	***
Shoot length (cm)	2.8bB	6.0a	5.1a	4.1B	6.1A	6.5A	*1.99*	*28*	NS	*

[a] Non-grazed.
[b] Spring grazing.
[c] Spring + autumn grazing.
[d] Autumn grazing.
[e] Residual standard deviation;
[f] Residual degrees of freedom.
[g] Means in the same row with different lower case or upper case letters are significantly different ($p < 0.05$) for stocking rate or grazing season effect, respectively.

5.2. Plants recovery

5.2.1. Survival

The number of living plants over the total number of plants one year after being consumed by goats showed that the survival rate (Fig. 1) was significantly affected ($p < 0.001$) by both, stocking density (83.1% vs. 63.7%) and grazing season. Surprisingly, the grazing season has, however, a clear influence on the subsequent mortality of the plants. The survival rate of bushes consumed both in spring and autumn (68.8%) was intermediate but significantly ($p < 0.001$) different from that of bushes consumed only in spring (93.1%) or in autumn (58.3%). The analysis also showed a significant ($p < 0.001$) stocking density × grazing season interaction, thus demonstrating that the effect of season was more pronounced at high stocking density.

5.2.2. Regrowth

Regrowth of plants one year after spring grazing was not significantly different from that of non-consumed bushes (Fig. 2). However, plants consumed

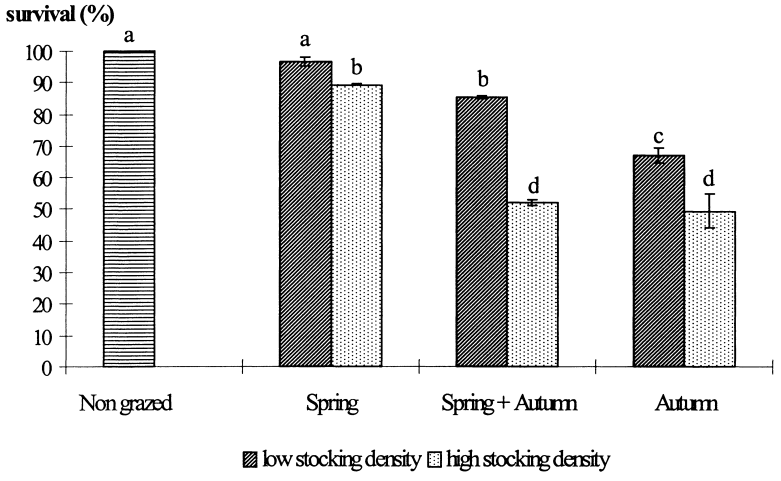

Fig. 1. Effect of stocking density and grazing season on *G. scorpius* survival.

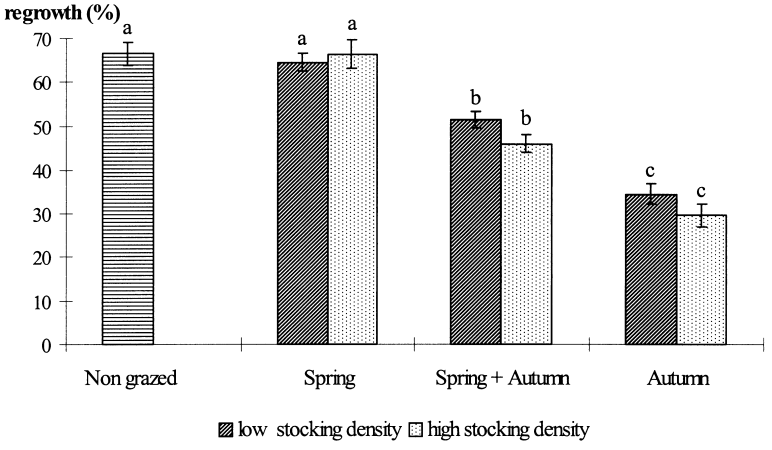

Fig. 2. Effect of stocking density and grazing season on *G. scorpius* regrowth.

during both seasons showed a 48.7% regrowth rate that was intermediate but significantly different ($p < 0.001$) from regrowth, shown one year later, by plants consumed either in spring (65.4%) or in autumn (32.0%). No significant effect of stocking density on regrowth rate was detected.

5.2.3. Flowering rate

Grazing appears to have a clear effect on flowering performance the next spring. While in the non-grazing treatment (NG), 38.5% of the plants were in flower, within the grazing treatments only 2.6% of living plants showed at least one flower next spring.

No big differences were observed in flower density between non-grazed plants and the main differences in flower quantity appears to be related to the size of the plant. To test this hypothesis, a regression equation was derived between the volume of eight non-consumed plants and the total number of flowers counted on them to estimate the variation between number of flowers and plant size:

$$\text{Number of flowers/shrub} = 1129.9 + 28956^{*}\text{Volume}(\text{m}^3); \quad r = 0.984^{***}.$$

From this relationship it was possible to estimate that the number of flowers on a mean-sized plant (0.138 m^3) was 5126. However, the number of flowers counted on browsed bushes ranged from 3 to 10 per plant.

5.2.4. Twig section consumed

In order to evaluate possible differences in *G. scorpius* utilisation due to grazing season and stocking density, the section of the twigs consumed was examined. After plant utilisation, the consumed twig section (Table 1) increased significantly ($p < 0.001$) from 1.8 mm in spring (S) to 2.8 mm in autumn (A) and was significantly thicker ($p < 0.001$) on high stocking-density (2.6 mm) than on low stocking-density (2.1 mm) treatments.

In order to assess the extent to which the consumed twig section may reflect the impact caused by livestock, the relationships between consumed twig section and the other plant parameters studied were examined. The consumed twig section (mm) appeared highly correlated to morphological modifications, such as volume reduction (%) ($r = 0.862^{*}$, $n = 6$), number of new shoots ($r = -0.895^{*}$, $n = 6$) and number of shoots per cm twig ($r = -0.851^{*}$, $n = 6$). Moreover, this parameter was also highly correlated with plant recovery responses, such as survival ($r = -0.989^{***}$, $n = 6$) and regrowth ($r = -0891^{*}$, $n = 6$) rates.

6. Discussion

Results obtained clearly show the impact that browsing has on *G. scorpius* plants. The consequences of plant/animal interaction were made evident, in the first place, by the morphological modifications shown by the plants. While stocking density has an effect on

plant volume and the number of new shoots, the plant is much affected by the time of browsing. Mean volume reduction significantly increased from the spring to the autumn grazing period. A similar effect was observed in the number of new shoots growing the following spring, with less shoots produced after browsing in autumn than in spring. This result agrees with that of Shepherd (1992), who observed that the number of new vegetative buds in Douglas-fir trees was greater when initial buds were removed early in the season.

The average number of new shoots per twig, however, was inversely related to the average length of these shoots, probably due to distribution of plant reserves available among the number of shoots. The effect of grazing season and clipping intensity on shoot length has also been observed in *Betula pendula* and *B. pubescens* (Danell et al., 1994), where winter browsing increased shoot size while a decrease occurred after summer browsing.

Goat browsing also has a remarkable effect on both, regrowth and flowering density and, consequently, on the plant's survival rate, both in the short and medium term, although the response of the plant is clearly different depending on the time of grazing. As vegetative buds are differentiated in summer on the latest growth, spring browsing allows bud development on the uneaten twigs portion. The number of new shoots per cm twig significantly increased with regard to that of uneaten plants, thus modifying the architecture of the plants consumed, which showed a more green and compact appearance than the untouched ones. Autumn browsing, however, removes almost completely green parts of the bush as well as the summer differentiated buds. The following year, new shoots have to be induced on older regrowth, leading to a 50% reduction in the estimated regrowth rate with respect to that in the non-grazed area. Also, ca. 50% of the plants do not survive the first year grazing, most probably due to the dramatic reduction in the green aerial parts of the plant. This effect notably increases with stocking density. These results agree with those of Grant et al. (1982) and Gregory and Wargo (1986) who observed that regrowth of both, *Calluna vulgaris* and *Acer saccharum* trees, respectively, decreased with later defoliation and could be related to the fact that autumn browsing may remove more photoassimilates than spring browsing. However, other factors appear to be involved, since the response of *G. scorpius* to browsing contrasts with the response given by this plant after mechanical or fire clearing, which shows, like *Genista hispanica*, a regenerative strategy inducing new shoots from ground level (Vera de la Fuente, 1994).

When *G. scorpius* is consumed in both the seasons, buds can be differentiated in summer on previous-year shoots equipped with strong and highly lignified thorns that would prevent new shoots from being reached by goats when reintroduced in autumn. Thus, bushes consumed by goats in spring and autumn will show a higher regrowth rate than those only browsed in autumn, which would give them greater survival chances than the latter ones. From all this it would appear that due to the phenology of this species and to the plant/animal interaction, autumn grazing is the most effective time for the control of *G. scorpius* by browsing.

The effect of grazing on shrub flowering (Roundy and Ruyle, 1989) as well as on fruit production (Schmutz, 1983) has been previously studied on another species, suggesting that grazing management strategies for limiting shrub density should be focused on reducing seeds population and its spread (Archer and Smeins, 1991). From this perspective, goat grazing on *G. scorpius* appear largely effective in reducing reproductive success since goat browsing has also shown itself to exert a clear effect on its reproductive organs. Flowering reduction in browsed plants may be explained by the fact that flower buds differentiate in summer on the current season's growths which have been mostly removed by goats. However, the exceedingly low number of flowers found in bushes consumed only in spring suggests that the level of plant reserves, as a consequence of defoliation, does not reach the level required for development of floral buds (Bernier et al., 1993). Thus, the plant responds to disturbance caused by herbivory giving priority to vegetative growth over flower buds differentiation as a way to ensure plant survival.

All parameters analysed have shown a good correlation with the size of the twigs eaten, this being used as a parameter to estimate differences in browsing ability between stocking density and grazing season. Thus, this parameter appears to reflect not only morphological changes but also further survival and regrowth performances of the shrub. Moreover, the

fact that mean, consumed twig section was an easily taken parameter suggests this measurement to be a useful index of the level of impact on bushes by livestock under extensive conditions. A similar effect between twig section consumed and morphological modifications has been previously observed on *Atriplex halimus* bushes (Valderrábano et al., 1996).

The success of plants against herbivory basically depends on the efficiency of their defence mechanisms or on their growing ability to replace the lost biomass (Herms and Mattson, 1992). While thorns have shown themselves to be efficient enough against most mammalian herbivores, browsing ability displayed by goats and the different response of *G. scorpius* to defoliation, depending on its phenological stage, both indicates that autumn grazing is the most adequate season for this bush control. However, pines can also be intensely browsed below 1.8 m (Torrano, unpublished data), which brings into question the value of using goats for scrub control in young pine stands. When there is no risk of trees being damaged by goat browsing, this alternative may provide foresters with a useful management tool for the control of *G. scorpius* bushes.

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