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Short-term study of effects of fertilisation and cutting treatments on the vegetation dynamics of mountain heathlands in Spain

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Abstract

The influence of management and nutrient availability on the vegetation dynamics of heathlands characterised by *Calluna vulgaris* and *Erica tetralix* were studied in three mountain sites in Northern Spain. A total of 90 plots (1 m^2 each) received different combinations of cutting and twice the estimated background atmospheric deposition of nitrogen (56 kg ha^{-1} yr^{-1}). One of the two dominant ericaceous species was selectively cut by hand at ground level and their regeneration compared in the presence or absence of the other. The results after 2 years showed significant effects of the fertiliser on the vegetation cover, mainly by favouring perennial herbaceous species. There were less noteworthy effects on the number of flowers and on the annual growth of the ericaceous species. It is concluded that, in the short term, increased nutrients alone, at twice the estimated current atmospheric deposition for the area, will not alter significantly the composition of the mountain heathlands. However, once the stands reach the mature phase, the capacity of the community to regenerate after a severe disturbance diminishes. A drastic impact, such as cutting may not result in re-growth of the same shrub species but in replacement by herbaceous species, which will also benefit from the increased nutrients.

Introduction

Heathlands are open landscapes characterised by dwarf shrubs of the family Ericaceae. Heathlands dominated by heather *Calluna vulgaris* have a restricted distribution in Western Europe. Although some heathlands occur under extreme conditions of temperature and exposure, where they are the climax vegetation, heathlands appeared in most cases after forest clearance, several thousands of years ago and were expanded and maintained by human activities, including the grazing of domestic animals and cutting of vegetation for peat and fuel (Webb 1998). Throughout their distribution in NW Europe, similarities in the climatic conditions, soil characteristics and management have maintained heathlands (Webb 1986). However, during the last century traditional management nearly disappeared in most countries due to changes in agricultural practices and for socio-economic reasons. As a result, and due to the plagioclimax stage they represent, scrub, bracken or other vegetation has been invading heathlands and altering their character.

The present study was carried out in the Cantabrian Mountains, N Spain, where areas of

Calluna vulgaris dominated heathlands still occur. Historically, a great part of the pastures and associated vegetation in the mountains of Northern Spain was used as summer grazing by flocks of merino sheep. The transhumance or practice of moving flocks and herds up to the summer pastures in the northern mountains and back to the valleys in central Spain in winter was widely practised for centuries. Heathlands and other shrub dominated vegetation types were regularly cut and burnt to provide pasture (Calvo et al. 2002). This type of management has changed during recent decades: agricultural policies have favoured a reduction in the number of sheep, from over half million in 1832 to just 10,000 in 2000 (Source: Junta de Castilla y León 2001), and an increase in cattle and horses based on subsidies.

In parallel with recent studies in NW Europe, records of atmospheric nitrogen deposition in mountain areas in Spain suggest an increase in the availability of this nutrient to the vegetation (Rivero Fernández et al. 1996). There is wide evidence in the literature of the negative effects of increasing nitrogen deposition on heathland ecosystems, a nutrient naturally scarce in these vegetation systems. For example changes from heathlands into grasslands have been reported in The Netherlands and Britain (Aerts and Heil 1993; Bobbink et al. 1998; Power et al. 1998a). In many cases these changes were favoured by a combination of factors, such as gaps in the shrub cover (due to e.g. overgrazing, frost damage or insect outbreaks) and increased availability of nutrients. However, there are no studies to determine the effects of nitrogen deposition on heathlands in the Cantabrian Mountains, one of the most southern areas of distribution of this type of vegetation.

The objectives of the present study were to determine the regenerative responses of two Ericaceous species: *Calluna vulgaris* (hereafter referred to as '*Calluna*') and *Erica tetralix* (hereafter referred to as '*Erica*') after experimental cutting under increased nutrient availability. Besides, the effects of cutting and fertilizer on the whole vegetation community were studied by looking at the variation on the life form types (woody species, annuals and perennials).

We investigated if cutting, which was a widespread form of heathland management in the past in the Spanish Cantabrian Mountains, could be an appropriate way of managing mountain heathland in systems with a decreasing number of domestic grazing animals. Cutting has been proposed as an alternative to grazing in areas where the latter is not economically or socially viable. Cutting to ground level is a drastic treatment and when it is carried out on the dominant species the result can be dramatic: micro-climatic conditions are altered and in some cases new, pioneer species may appear in the resulting bare ground. We looked at regeneration of two typical heathland species after the above-mentioned treatments. This study was also carried out in three mountain sites with different characteristic to assess the consistency of the results.

We also looked at the effect of fertilizer on the production of flowers, as this may affect the seed production capabilities of the species. We also considered the impact of fertiliser on shoot-growth as a measure of recovery after cutting.

Materials and methods

Study sites

Three mountain sites, located approximately 25 km from each other, were selected in 1998 in the province of León (NW Spain): San Isidro (1600 m a.s.l., 43°03′ N, 1°40′ W), Tarna (1625 m a.s.l., 43°04′40″ N, 1°33′ W) and Vegarada (1585 m a.s.l., 43°02′20″ N, 1°48′20″ W). The average annual temperature is 5.5 °C and the average annual rainfall is 1320 mm in all areas. The climatic conditions are typical of the Atlantic Region and are characterised by a warm season with no (or less than 2 months) dry period. The study sites contain a range of different soil conditions, with variations in particular in soil moisture (Tarna is the wettest and San Isidro the driest) organic matter and nutrient content (nitrogen and phosphorus). Soils in all sites are podsols, although the underlying geology is different. The initial soil characteristics of the three study sites are represented in Table 1. Differences between Tarna, which has a peaty, organic superficial horizon, and the other two sites were statistically significant ($p < 0.05$) for organic matter, nitrogen and phosphorus content. All sites had a low pH (average 4.1) although Vegarada had a significantly higher pH than the other two sites. In the

Table 1. Soil characteristics before the treatments in the three study areas.

	San Isidro	Tarna	Vegarada
Underlying rock	Quartzites	Sandstones and lutites; calcareous outcrops	Granites and slates
pH	3.9 (0.2)a	4.0 (0.3)a	4.3 (0.2)b
Organic matter (%)	21.3 (6.8)a	47.2 (16.8)b	26.5 (5.4)a
Total nitrogen (%)	0.7 (0.4)a	1.16 (0.4)b	1.0 (0.3)ab
Available phosphorus (ppm)	17.6 (3.3)a	14.5 (5.5)ab	11.33 (3.2)b

Standard deviation is shown in brackets. Different letters in the same row indicate significant differences ($p < 0.05$) between areas.

latter case an acid layer was found over a layer of limestone rocks, which in some places reached the surface. Tarna, on the other hand, had a low pH and high organic matter and N and P content.

Experimental design

In April 1998, a random area of approximately 1–2 ha where *Calluna* and *Erica* were present was selected in each site. The three sites did not differ significantly in their productivity for each species (Marcos et al. 2003). The highest biomass value corresponded to *Calluna*, with between 1295 and 1857 g m^{-2}. *Erica* had lower values, between 186 and 102 g m^{-2}. There are no records of when they were burned or cut for the last time, but all the stands were in a mature stage (sensu Watt 1955). Randomised block design was used, so each area was a block where the same treatments were repeated.

Six 1 m^2 fixed plots were established in April 1998 in each site. On the selected areas, vegetation structure and soil nutrient levels were altered using different and random combinations of cutting and fertilisation. The treatments were: two control plots, two plots where *Calluna* was cut by hand at ground level (C), two where *Erica* was cut likewise (E). The cutting/removal treatment was applied only once at the start of experiment and the clippings were removed and used to determine the average biomass (total dry mass per square meter) of *Calluna* and *Erica*. One of each of the two-paired plots (control plots, *Calluna* cut plots and *Erica* cut plots) received an application of nitrogen (as ammonium nitrate) fertiliser within 2 weeks of the snow melting in the sites each year (late April, early May).

The fertiliser treatment was applied every year from 1998 until 2001. The fertiliser level (56 kg ha^{-1} yr^{-1} as weight of fertiliser) was chosen to be equivalent to twice the estimated current background pollution levels in this area (Rivero Fernández et al. 1996).

The codes given to each treatment and plot are:

1.	Control	No fertilization	O-uF
2.	Control	Annual fertilization	O-F
3.	Removal of *Calluna vulgaris*	No fertilization	C-uF
4.	Removal of *Calluna vulgaris*	Annual fertilization	C-F
5.	Removal of *Erica tetralix*	No fertilization	E-uF
6.	Removal of *Erica tetralix*	Annual fertilization	E-F

Five replicates were established in each site, giving 30 plots per site and 90 plots in total. That is three treatments: Control (O), *Calluna* removal (C) and *Erica* removal (E) and two fertilization treatments: unfertilised (uF) and fertilized (F), were used in a randomised block design with five replication of each in three different sites (Vegarada, Tarna y San Isidro).

Chemical analysis of soil

Twenty soil cores were collected at each study site at 5 cm depth to establish the pH before the treatments and the levels of nutrients occurring naturally in the soils. The samples were air-dried, sieved (2 mm diameter) and ground prior to analysis. Soil pH was determined in a ratio 1:2.5 in water. Total organic matter and total nitrogen were determined by Walkey and Black (1934) and Kjeldahl (Bremner 1960) methods respectively. Available phosphorus was determined by the Bray–Kurtz method (Kalra and Maynard 1991).

Vegetation sampling

Initial experimental measurements were made in order to establish the baseline characteristics of the vegetation at the experimental sites, prior to the treatments being applied. Measurements are summarised below:

1. The percentage cover of each species was estimated visually in each sampling unit of one square meter in all replicates. The data were used to determine abundance, diversity (H') (Shannon index) (Shannon and Weaver 1949) and its two components, richness (S = species number) and evenness ($J' = H'/H'_{max}$).
2. The maximum height per plot of *Calluna* and *Erica* was measured as a single measurement of the tallest plant of each species. The average values of the five replicates were used to define the maximum height.

These measurements were carried out immediately before the treatments, after a month, after two months and later annually.

After the treatments, the number of flowers per shoot and the current year shoot length for both for *Calluna* and *Erica* were counted just once each year (in August) on five randomly selected shoots for all replicates in all of the treatments.

Plant nomenclature follows Tutin et al. 1964–1980.

Data analysis

The cover values of each vascular species were used to determine the cover of the following life forms: woody, perennial species and annual species.

Percentage cover of *Calluna vulgaris*, *Erica tetralix*, the life forms and structural parameters (richness, evenness and diversity) were analysed by means of factorial analysis of variance. For statistical analyses, data expressed as percentages of cover were arcsine-square root transformed prior to analysis and analysed by repeated-measures analysis of variance, with time as the repeated-measures variable and, control, cut, fertilization, and study sites as factors. If the repeated measures test (General Linear Model) detected significant interactions between time and treatment for each dependent variable, one way ANOVA test was carried out for each sample data separately. Tukey-tests were carried out to determine the significance of the differences. Statistical tests were carried out using Statistical Program for the Social Sciences 11.5 (SPSS Inc. 1989–2002).

Results

Changes in Calluna and Erica cover and height after cutting and fertilising

The original situation consisted of a high percentage cover of *Calluna* in the three study sites (between 50 and 85%), without significant differences between the three sites ($F = 2.086$; $p > 0.05$). *Erica* accounted for only between 10 and 30% of cover, again without significant differences ($F = 2.388$; $p > 0.05$). Under these circumstances, when only *Calluna* was cut on its own there was a drastic change in the community structure and cover. In contrast, the cutting of *Erica* alone did not have a significant effect, as shown in Figure 1. This, together with the different morphology and growth patterns of both species (*Erica* recovering faster) meant that after 2 years *Erica* had almost recovered its original cover and height for most treatments and study areas.

There is no significant effect of fertilization on *Calluna* cover (Figure 1) over the whole period, neither in the uncut control plots ($F = 3.59$; $p > 0.05$), nor after cutting it ($F = 3.383$; $p > 0.05$), even when the co-dominant species was removed ($F = 2.390$; $p > 0.05$). The responses of *Calluna* in all sites did not show significant differences.

The addition of fertiliser did not affect significantly the recovery of *Erica* after the cutting treatments in any site ($F = 2.02$; $p > 0.05$) although this species recovered significantly faster than *Calluna* ($F = 4.04$; $p > 0.05$).

Twenty-four months after treatments the cover of *Erica*, in the plots where *Calluna* was cut, was significantly higher than cover of *Calluna*. This was evident in both, the *Calluna* cut unfertilised (C-uF) ($F = 13.184$; $p < 0.05$) and in the *Calluna* cut fertilised (C-F) ($F = 9.786$; $p < 0.05$) plots. *Erica* had over 20% cover, whereas *Calluna* was below 10%.

Figure 2 shows changes in the mean maximum height of *Calluna* and *Erica* in the three study sites. *Erica* is in general shorter than *Calluna*, but in areas were heather is denser *Erica* grows taller, probably in order to compete for light. *Calluna* re-growth was similar in all plots where it was cut and the height at the end of the experiment was still about half that of the original situation, as expected for this species after

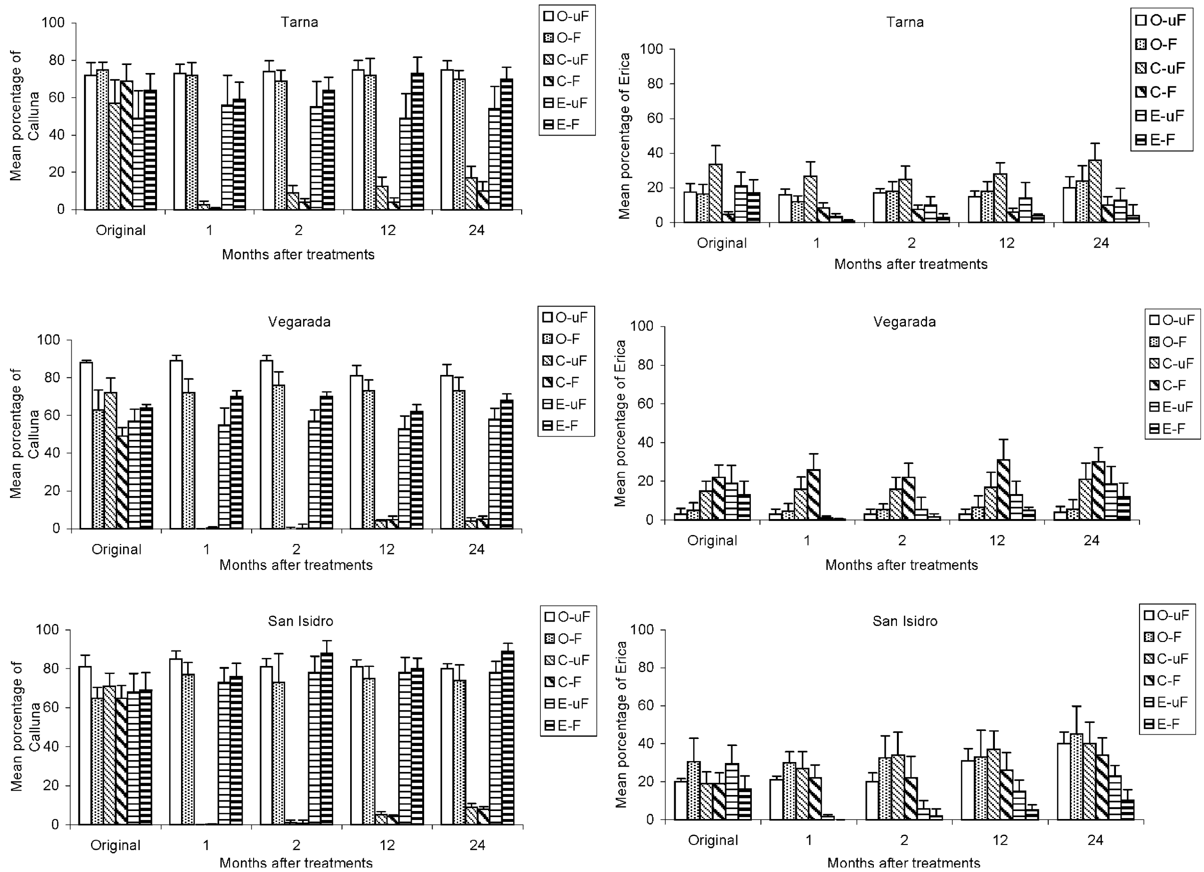

Figure 1. Percentage cover of *Calluna vulgaris* and *Erica tetralix* under different treatments (mean and standard error) for three study areas (San Isidro, Vegarada and Tarna) in the original situation and 1, 2, 12, 24 months after treatments. O-uF = control without fertilization, O-F = control plus fertilization, C-uF = *Calluna*-cut without fertilization, C-F = *Calluna*-cut plus fertilization; E-uF = *Erica*-cut without fertilization; E-F = *Erica*-cut plus fertilization.

only 2 years. Fertiliser did not affect the height of established *Calluna* after the first application but it promoted shoot re-growth, which appeared earlier under increased nutrient availability (pers. obs.). The same effect was observed in the three sites. However, fertiliser allowed *Erica* to reach its original height in this short period of time in Vegarada and San Isidro in those plots where it had been cut. Twenty four months after the treatments, and excluding the control treatment, *Calluna* maximum height was the highest in the fertilised plots where *Erica* was cut (E-F). This effect is clearer specially in Tarna, but it is evident in all sites when compared with the original situation. Reduced competition and more nutrients resulted therefore in a taller (but not denser) dominant species.

Erica height increased the most in the uncut fertilised plots and in the *Erica* cut fertilized plots (Table 2). However in the removal of *Calluna* did not result in a common trend in all sites.

Flower numbers and shoot growth of Calluna and Erica

No significant differences were found between sites in the number of flowers ($F = 1.859$; $p > 0.05$) and the growth of the shoots ($F = 0.446$; $p > 0.05$) of *Calluna* in the control plots. In some cases, regeneration was not fast enough for the plants to produce flowers and therefore this parameter was not measured. The average number of flowers in *Calluna* plants was very homogeneous

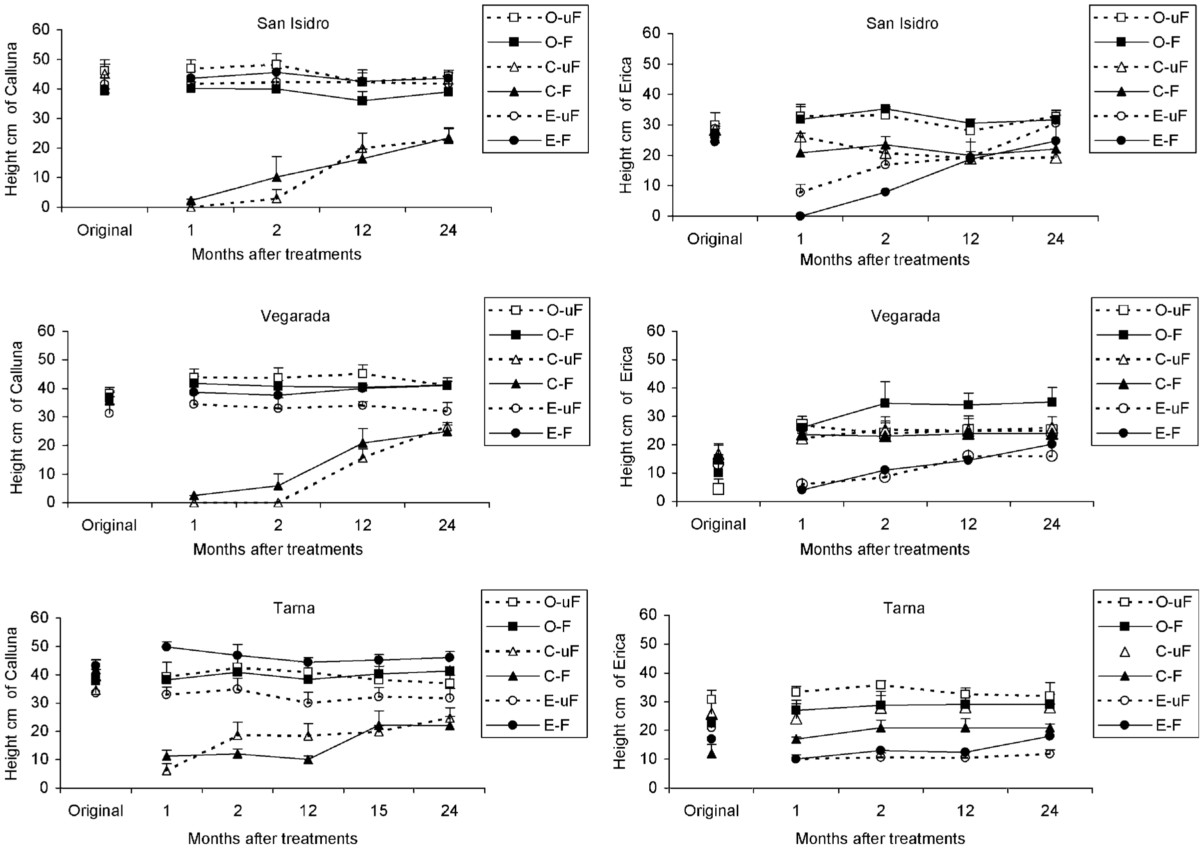

Figure 2. Changes in the maximum height of *Calluna* and *Erica* for each treatment along time (mean and standard error) for three study areas (San Isidro, Vegarada and Tarna) in the original situation and 1, 2, 12, 24 months after treatments. (Codes as for Figure 1).

Table 2. Increase in the average maximum height (cm) of *Calluna vulgaris* and *Erica tetralix* 2 years after treatment in relation with original situation.

Site	O-uF	O-F	C-uF	C-F	E-uF	E-F
Calluna vulgaris						
Vegarada	2.8	4.4	−8.94	−10.6	0.8	5.4
San isidro	−1.8	−0.4	−19.2	−16.6	0.2	3.6
Tarna	−1	3	−9.85	−19.8	−1.8	2.8
Erica tetralix						
Vegarada	20.6	24.8	9.2	8.8	2.8	4.85
San Isidro	2.8	4.67	−9.25	−3.5	1.8	0.35
Tarna	1.2	6.4	2.2	9	−9.2	1

in Tarna and Vegarada (range 8.6–11.3) in the unfertilised plots. For some unknown reason, this range was greater in San Isidro (7.4–14.2). The standard errors of the means were similar in all cases between (4 and 12%). The differences in the average number of flowers were not significant in time ($p > 0.05$), although during the second year this average was higher in the fertilised plots. *Erica* produced an average of 8–15 flowers and the differences were not significant between sites ($F = 0.454$; $p > 0.05$) or treatments.

The average annual growth of *Calluna* shoots varied between 2 and 5 cm in the first year to 4–7 cm two years after the treatments. On the other hand, the average *Erica* shoot growth ranged between 3 and 7 cm annually. These differences in time were only statistically significant ($F = 6.861$; $p > 0.05$) for *Calluna* and *Erica* in the unfertilised plots of San Isidro. The differences were only statistically significant for *Calluna* in San Isidro and Vegarada in the 'EF' plots (*Erica*-cut and fertilised). The inhibition of the competition by cutting *Erica* plants did not affect the growth of *Calluna* shoots either ($F = 0.016$; $p > 0.05$).

In summary, neither the number of flowers, nor the growth of the shoots in *Erica* or *Calluna* was affected significantly by any of the treatments or by time.

Changes in the vegetation cover of the other species in the community

Figure 3 shows the changes in the percentage cover of the vegetation grouped as annual and perennial herbaceous species and woody species for Tarna. There were no significant differences between the study areas and therefore the result shown for Tarna represent the other two areas as well. The cover of annual species, which were naturally scarce in all three passes as expected from old heathland stands (Calvo et al. 2002), was not significantly affected by either treatment (cutting or nutrient addition). The most common annual

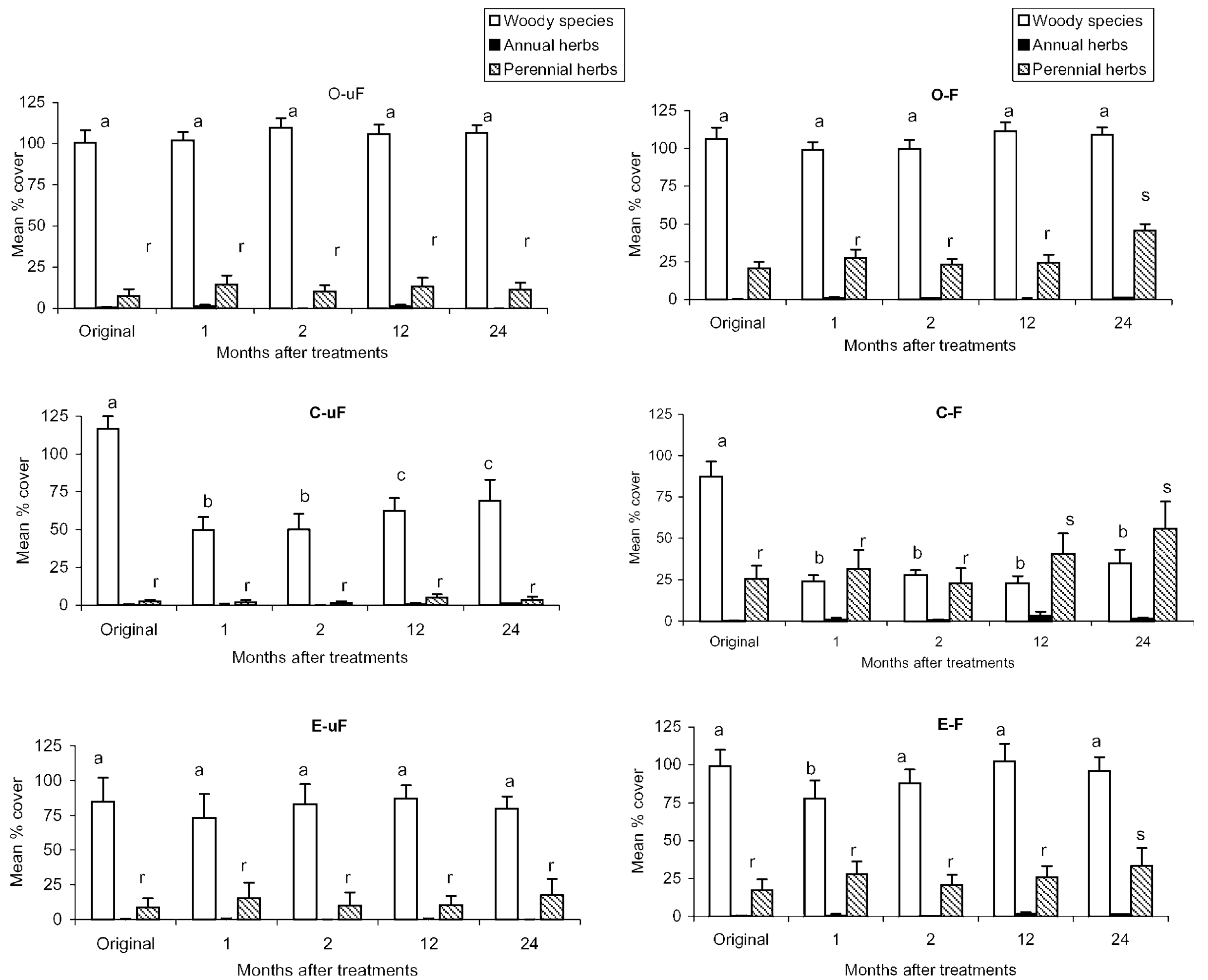

Figure 3. Percentage cover of the life forms (annual herbaceous species, perennial herbaceous species and woody species) under different treatments (mean and standard error) for Tarna. a, b, c: represent significant differences ($p < 0.05$) for the woody species in time; r, s, t: represent significant differences ($p < 0.05$) for the perennial herbaceous species in time.

species in all three sites were *Aira caryophyllea* and *Jasione montana*. There were not significantly differences between control unfertilised and control fertilized ($F = 0.001$; $p > 0.05$) in the cover of woody species. The cover of perennial herbaceous species increased significantly after fertilization in both, the control plots ($F = 8.57$; $p > 0.05$) and in the cut plots ($F = 8.55$; $p > 0.05$). The perennial herbaceous species with highest cover values in all three sites were *Carex nigra*, *Stellaria holostea*, *Potentilla erecta*, *Nardus stricta*, *Juncus squarrosus*, *Festuca rubra* and *Deschampsia flexuosa*.

After the *Calluna* cut treatment the recovery of woody species is slower in the fertilized plots than in unfertilised ones. However, removing *Erica tetralix* had no significant effect ($F = 0.503$, $p > 0.05$) on the performance of other woody species regardless of the fertilization treatment. Other woody species apart for the ericaceous were *Vaccinium myrtillus* and *Polygala microphylla*.

Structural parameters of the community (diversity and its components)

The study of the structural parameters refers here to the species composition and not the physical structure of the canopy. Figure 4 shows the variation in structural parameters throughout the study period in San Isidro (other study areas not shown). In general, the *Calluna* cutting treatment increased structural diversity through the elimination of dominant species, allowing an opportunity for other species to colonise the resulting gaps. In San Isidro, a botanically poor area, the treatments did significantly ($p > 0.05$) alter several of the structural characteristics (evenness, richness, diversity). However, cutting *Erica*, which originally had a low cover, had no significant effect ($p > 0.05$).

Fertilization increased significantly the species richness in the uncut plot ($F = 6.608$; $p > 0.05$) and in the *Calluna* cut plots ($F = 11.00$; $p > 0.05$). However, fertiliser did not increase richness after cutting *Erica* ($F = 0.336$; $p > 0.05$). Changes in diversity are similar to those of species richness.

Structural parameters were significantly different in all three areas. In Tarna, the range of species richness was greater. Significant differences in terms of species richness and diversity were found for the fertiliser and cutting treatments, as well as for the interaction between these treatments. There was no significant effect of the fertiliser in Vegarada.

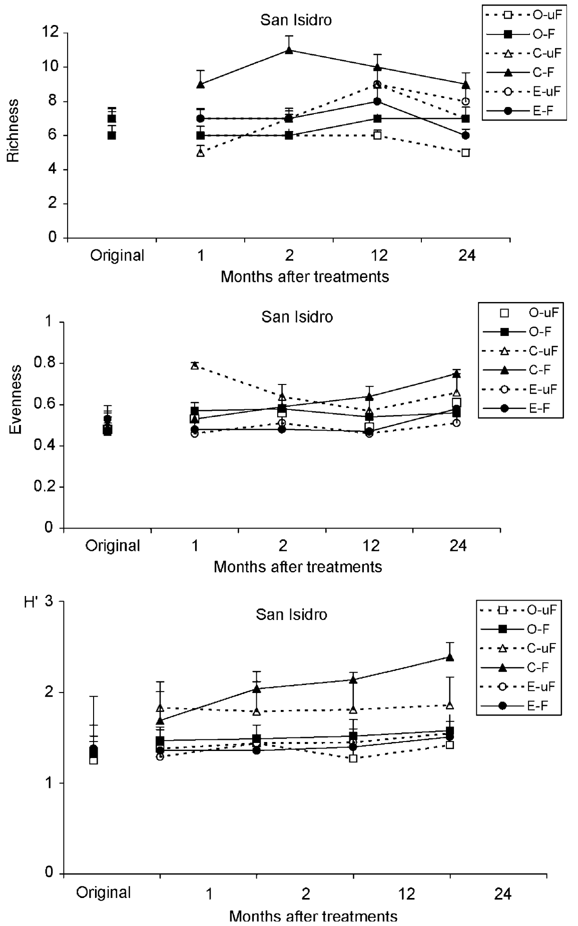

Figure 4. Variations in the structural parameters in San Isidro under different treatments (mean and standard error) in the original situation and 1, 2, 12, 24 months after treatments (codes as for Figure 1).

The evenness values did not differ significantly between either sites, time or treatments.

Discussion

The regeneration of heathland species after cutting depends very much on the condition of the initial heather canopy, on the abundance and behaviour of herbivores, which select their diet in relation to nutrient content, on the persistence of the soil seed bank and on the climatic conditions (Calvo et al. 1992; Alonso et al. 2001). Perennial species, with a greater representation in the seed bank (Valbuena et al. 2003), and able to regenerate from their basal rosettes, are in a better position to take advantage of changing, more favourable conditions, as a result of increased nutrients and light availability. *Calluna* stands regenerated poorly and slowly after the cutting treatment, which may have been due to the age of the original stands (estimated at over 20 years old). Old heather stands generally show poor regeneration (Mohamed and Gimingham 1970). *Erica tetralix* on the other hand showed in general a better regenerative response, which could be due to its particular growth form, with thin and branched stems and the fact that it regenerates better from buried stools (Bannister 1966). When *Calluna* was cut, *Erica* increased its cover in San Isidro, as previously observed in other studies carried out in the same area (Calvo et al. 1992, 2002), but not in the other two study areas.

Fertiliser did not produce significant effects for most of the parameters measured, demonstrating that twice the rate of current atmospheric deposition is not enough to affect vegetation dynamics in these mountain areas in the short term (2–3 years). Furthermore, it has been observed that the average nitrogen content in the soil decreases with time after the fertilization (Marcos et al. 2003). Long-term studies could demonstrate different conclusions.

One of the main effects of N addition was the increase in the cover of perennial herbaceous species in all the experimental sites. Herbaceous species have faster growth rates and respond more quickly to the increase in nutrients than slow growing shrubs (Heil and Bruggink 1987). Results from studies in heathlands in The Netherlands showed a strong relationship between increased nitrogen deposition and the replacement of shrubs by grasses (Berdowski and Zeilinga 1987; Prins et al. 1991). However, many authors have shown that if the original shrub cover is not under stress (e.g. overgrazing), the woody species have competitive advantages over herbaceous species such as *Nardus stricta* (Alonso and Hartley 1998) or *Molinia caerulea* (Heil and Bruggink 1987) in the longer term. Since vegetative regeneration of heather is rare in old stands (Calvo et al. 2002), cutting treatments could lead to the replacement of this community by those dominated by the characteristic grasses (*Nardus stricta*, *Festuca rubra*, *Deschampsia flexuosa*) under increased nutrient (N) availability.

One of the factors to consider in order to determine the impact of atmospheric deposition on the vegetation is the soil characteristics. The studied areas in this case had a low pH, high organic matter content and low values of phosphorus nitrogen and cation nutrients. A low pH can cause toxicity effects in the plants, reduced microbiological activity, low nitrification and slow organic matter decomposition (Martínez et al. 2000). One of the parameters that determine nitrogen availability is the C/N ratio of the litter humus. The C/N ratio in the studied passes was: Vegarada C/N = 28.02, San Isidro C/N = 35.56, Tarna C/N = 35.72 (Calvo, non-published data). Porta et al. (1999) suggested that a ratio of greater than 15 indicates a very low nitrogen release. It could therefore be assumed that atmospheric deposition of nitrogen could potentially accelerate growth of vegetation in these sites, as a result of decreased C/N ratios and an increase in the release of nitrogen in an available form.

Calluna showed relatively limited and slow response to applications of fertiliser, in contrast to results from other workers (Marschner 1986; Caporn et al. 1994; Pitcairn et al. 1995; Power et al. 1998a; Carroll et al. 1999). There could be various explanations for this response: (i) the age of the plants and their reduced ability to respond to changes in their environment (nutrient or disturbances) (Kirkham 2001); (ii) an increase in inorganic nitrogen may affect negatively the plant mycorrhiza symbiosis (Stribley and Read 1976; Yesmin et al. 1996). Mycorrhizas release enzymes that allow Ericaceous access to nitrogen from the soil organic matter (Leake and Read 1989) and any alteration in their functioning may have negative consequences for the dwarf shrubs; (iii) increases in nitrogen availability affects soil pH by producing changes in mineralization (Lee 1998) and indirectly influences seed germination, mainly of *Calluna*. Germination of this species decreases in low pH soils (Diemont 1990); or (iv) the amount of fertilizer in this experiment was lower than that used by other authors in other countries, which might have influenced the regeneration of *Calluna* stands. Fertilisation did however benefit *Erica tetralix* by increasing its height faster.

The interactive effects of disturbances such as overgrazing and increased atmospheric deposition have been shown to favour herbaceous species competing with ericoid species (Alonso and

Hartley 1998) and can lead to changes in community composition (Chapin and Shaver 1985). However it seems clear that increased nutrient availability *per se* is not enough to trigger this change (Heil and Bruggink 1987; Prins et al. 1991; Heil and Bobbink 1993). The role of the nutrients is very complicated and changes in the species composition of a heathland will depend not only on an increase in nutrient availability, but also on the growth phase of the dominant species, as well as other factors such as stress due to drought or frost (de Smidt 1977; Power et al. 1998b). Competition models developed for heathlands in The Netherlands showed that an input of 17–22 kg N ha^{-1} yr^{-1} is the critical load which tilted the balance from a wet heathland towards grassland (Berendse 1988), whereas a lower input (15–20 kg N ha^{-1} yr^{-1}) may be enough in dry heathlands in that country (Heil and Bobbink 1993). In the case of the Cantabrian Mountains heathlands, higher nutrient inputs (56 kg ha^{-1} yr^{-1}) did result in significant vegetation changes in the short term in the perennial herbaceous species, although not in the characteristic woody species or in the number of flowers or shoot growth. However fertilisation in the long term increases the production of flowers as observed by Iason and Hester (1993), which may lead to changes in the seedbank with possible consequences for future community composition.

The management of the heathland communities in the northern Spanish uplands, with an appropriate stocking rate in these dry areas, could help to maintain a young and healthy heather cover, which will constitute an ideal habitat for a variety of wildlife and to remove some of the nutrients deposited atmospherically.

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