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Effects of long-term grazing management on dandelion (*Taraxacum officinale*) in *Agrostis capillaris* grassland

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Abstract

Dandelion (*Taraxacum officinale* agg.) is a common forb species in grasslands in Europe. Although sometimes regarded as a valuable forage herb, it may become a weed, especially in arable land. There is limited information on the response of *Taraxacum* to long-term grassland management practices. Therefore, we analysed cover and dry-matter standing biomass of *Taraxacum* in a long-term (1998–2012) grazing experiment on an *Agrostis capillaris* grassland. The following treatments were laid out on formerly abandoned grassland: (i) intensive grazing (IG); (ii) extensive grazing (EG); (iii) first cut followed by intensive grazing (ICG); (iv) first cut followed by extensive grazing (ECG); and (v) unmanaged grassland (U). During the first 10 years, all defoliation treatments (i–iv) supported the presence of *Taraxacum*, and the lowest proportion was recorded in the unmanaged treatment (U). During the final 7 years of the study, combined cutting and grazing promoted *Taraxacum* cover more than that of grazing only (ICG > IG > ECG > EG). Cover of *Taraxacum* was negatively affected by increasing sward height where *Taraxacum* plants had lower fitness. Due to the relatively strong relationship between percentage cover of *Taraxacum* and its dry-matter biomass, percentage cover could be used as a simple method for the assessment of biomass of *Taraxacum* in a sward. Results are discussed in the context of adapting the management of *A. capillaris* grassland as a simple method for control of *Taraxacum* abundance, particularly in situations of extensification or abandonment.

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Introduction

Dandelion [*Taraxacum* sp. (Asteraceae)], generally referred to by the collective name of *Taraxacum officinale* agg. (Kirschner and Štěpánek, 2011), is a perennial herb native to Europe. It occupies a wide range of habitats, especially pastures, lawns and meadows (Grime *et al.*, 1988) where it frequently has the status of a weed species. It can become aggressive and invasive due to its high plasticity and ecotypes with different ecophysiological traits, which allow it to occupy a wide range of environmental conditions (Molina-Montenegro *et al.*, 2013). Its weed status is also partly the result of its high seed production, dispersal and germination potential (Abu-Dieyeh and Watson, 2007).

Although dandelion is frequently considered to be a weed, especially in arable land, its weed status in grassland is less straightforward. Its herbage has a low dry-matter content which can cause problems with forage conservation, especially losses during mechanical hay making (Isselstein and Ridder, 1993; Stewart-Wade *et al.*, 2002). On the other hand, its presence in grassland has potential to contribute to the overall forage value of the sward (Stewart-Wade *et al.*, 2002; Assaf and Isselstein, 2009). For example, it is reported to have a high content (150–220 g kg^{-1} DM) of crude protein (Khan *et al.*, 2013), high digestibility with over 700 g kg^{-1} of digestible organic matter (Hoveland *et al.*, 1986; Marten *et al.*, 1987), and it also has high concentrations of some minerals, especially K and Mg (Harrington *et al.*, 2006; Grzegorczyk *et al.*, 2013). Therefore, dandelion can also be considered as a valuable forage species in some situations and significantly increase the quality of pasture biomass (Pavlů *et al.*, 2006).

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In established grassland swards, dandelion seedling establishment is suppressed by the effect of reduced light conditions at the base of the sward, and by the more vigorous growth of grasses especially in response to increased N and K supply from fertilizer applications (Tilman *et al.*, 1999; Klimeš *et al.*, 2003; Lanta *et al.*, 2009). On the other hand, dandelion plants can also be strongly supported by high rates of fertilization, as shown by the results of 80 years of application of NPK fertilizers in the Steinach Grassland Experiment (Hejcman *et al.*, 2014). In contrast to meadows that are managed predominantly by mowing, pastures are influenced by several additional factors, such as trampling, nutrient returns from dung and urine, and selective defoliation by animals (Ludvíková *et al.*, 2014). Because *Taraxacum* species are often present in vegetation developed on dung and urine patches, they have been assigned a better N-indicator status than most pasture grasses (Ellenberg *et al.*, 2001).

The competitive ability of dandelion in swards is positively correlated with increasing defoliation frequency, both in meadows (Gaisler *et al.*, 2006; Pavlů *et al.*, 2011) and in pastures (Pavlů *et al.*, 2007; Schleip *et al.*, 2013; Ludvíková *et al.*, 2015). Increased defoliation results in increased light availability and thus better conditions for its greater abundance (Hejcman *et al.*, 2010). On the other hand, in species-rich grassland, dandelion also occurs at sites without defoliation, where high contents of plant litter are recorded (Lanta *et al.*, 2009). In pastures, grazing in conjunction with trampling are important factors for creating gaps, and this determines the abundance of seedlings and encourages seedling emergence of dandelion (Martinková *et al.*, 2009).

It might be expected that different grassland management treatments would affect *Taraxacum* differently over the long term, but most studies have been based on short-term experiments of <6 years duration (Harker *et al.*, 2000; Lanta *et al.*, 2009; Dumont *et al.*, 2011; Novák *et al.*, 2013). Therefore, the presence of a long-term manipulative grazing experiment on *Agrostis capillaris* grassland, which commenced in 1998, has provided an opportunity to analyse a continuous vegetation data set for a site where dandelion became one of the dominant grassland species (Pavlů *et al.*, 2007). Preliminary results from this experiment revealed that any management imposed on abandoned grassland supported fast development of dandelion cover and density in the first six years (Pavlů *et al.*, 2006, 2007). Furthermore, cutting and grazing in combination, regardless of intensity, were more favourable for the spreading of dandelion than grazing alone. However, to confirm this initial trend, we evaluated 15 years of manipulative grassland management in relation to the presence of dandelion. With respect to the aforementioned facts, we addressed the following questions: (i) How do different grazing management regimes affect the cover and standing biomass of dandelion in the course of a long-term grazing experiment?; (ii) What is the relationship between plant cover and standing biomass of dandelion?; and (iii) Which grassland management is the most suitable for controlling the spread of dandelion?

Material and methods

Study site

The study site is located in the Jizerské hory Mountains, northern Czech Republic, in the village Oldřichov v Hájích situated 10 km north of Liberec (50°50′N, 15°06′E; 420 m above sea level). The mean annual precipitation is 803 mm, and the mean annual temperature is 7·2°C (Liberec Meteorological Station). The bedrock is biotic granite, and this is overlain with medium-depth Cambisol with a pH (KCl) of 5·45 and an organic-C content of 4·53%. The contents of plant-available P, K, Ca and Mg using the Mehlich III method (Mehlich, 1984) were 28, 67, 1728 and 58 mg per kg of soil respectively.

The experimental site was drained, ploughed and reseeded with a highly productive grass–legume mixture in the early 1980s, and then managed intensively by cutting and grazing. In the early 1990s, mulching (mowing and chopping the plant biomass into 5–10 cm lengths, and deposited as a homogenous layer on the sward surface) was applied once a year (in August), and the grassland utilization was abandoned. When the experiment started in 1998, there had been no agricultural management during the previous 5 years. Prior to the introduction of experimental treatments in 1998, the grassland was classified as an upland hay mesophile meadow (alliance *Arrhenatherion*), but in later years, the alliance *Cynosurion cristati* (Chytrý, 2007) developed successively under long-term grazing management. The dominant species are *Agrostis capillaris*, *Festuca rubra* agg., *Trifolium repens* and *Taraxacum* spp. In May 2002, during fieldwork to provide an inventory of *Taraxacum* (Bohumil Trávníček, unpubl. obs.), the following species were recorded: (i) Section. Taraxacum: *Taraxacum aberrans*, *T. alatum*, *T. ekmanii*, *T. fasciatum*, *T. horridifrons*, *T.lacinulatum*, *T. lundense*, *T. ochrochlorum*, *T. pallidipes*, *T. piceatum*, *T. sertatum*, *T. sinuatum* and *T. aequilopbum* agg.; (ii) Section Hamata: *T. hamatiforme* and *T. lamprophyllum*. Because of difficulties in determination during the entire experiment, all presented *Taraxacum* species were thereafter referred to as *Taraxacum officinale* agg.

Experimental design and plot management

The long-term grazing experiment, referred to as the 'Oldřichov Grazing Experiment' (OGE), was established in the spring of 1998 and arranged in two randomized blocks (Pavlů *et al.*, 2007). Each block consisted of five paddocks where the following treatments were applied: (i) extensive grazing (EG) in which the stocking rate was adjusted to achieve a mean target sward surface height of more than 10 cm; (ii) cutting in June followed by extensive grazing (ECG); (iii) intensive grazing (IG) in which the stocking rate was adjusted to achieve a mean target sward surface height of less than 5 cm; (iv) cutting in June followed by intensive grazing (ICG); and (v) unmanaged grassland (U). Each grazed paddock was circa 0·35 ha, and the U paddock was 0·12 ha. All grazed paddocks were continuously stocked by young heifers (initial live weights of 150–250 kg) in each grazing season from early May until late October. The mean productivity of the pasture has been found to be in the range 2–4 t DM ha^{-1} $year^{-1}$ (Pavlů *et al.*, 2007). The sward surface heights were measured weekly across each experimental plot (100 measurements) using a rising plate meter (Correll *et al.*, 2003), and stocking density was adjusted accordingly by increasing or decreasing the area available for grazing. The herbage biomass harvest in the ECG and ICG treatments was performed using a tractor with three machines: one for cutting at 3–5 cm, a haymaker and a pickup hay-loader. The cut was taken at the beginning of June, which is the traditional time for hay making in this upland grassland area, and after anthesis of *Taraxacum*.

Data collection of cover and standing biomass of *Taraxacum*

Permanent 1 m × 1 m plots were analysed using a continuous grid of nine 0·33 m × 0·33 m subplots in four replications per paddock. Percentage cover of all vascular plant species in each subplot was estimated visually just before the start of the grazing season in early May of each year from 1998 to 2012. The mean of nine subplots was used for statistical evaluation.

To determine the standing biomass of *Taraxacum*, in early May each year of 2001–2012, six samples were collected from randomly positioned 0·50 m × 0·25 m quadrats after cutting with electric shears at ground level in each paddock. Samples were frozen at −20°C and later sorted into *Taraxacum*, graminoids, forbs other than *Taraxacum*, mosses and legumes, and then subsequently dried for 48 h at 70°C and weighed. Standing dry-matter (DM) biomass data were recalculated (as g DM m^{-2}). The results in this paper are based on analysis of the standing biomass data of *Taraxacum* only. A standing biomass/cover ratio was calculated to provide an evaluation of fitness of *Taraxacum* plants in the existing sward.

Data analysis

Repeated measures analysis of variance (ANOVA) was used to evaluate the annual variation of cover of *Taraxacum*. One-way ANOVA was then used to test differences among treatments for cover of *Taraxacum* in a particular year and standing DM biomass (g m^{-2})/cover ratio of *Taraxacum*. Further post hoc comparison using the Tukey's HSD test was applied to identify significant differences between individual treatments. Linear regression was used to analyse the relationships between: (i) percentage cover of *Taraxacum* and percentage cover of other vascular plant species, (ii) percentage cover and standing biomass of *Taraxacum*, and (iii) percentage cover of *Taraxacum* and mean sward height recorded during sampling. Statistica 10.0 software was used to perform all univariate statistical procedures (StatSoft, 2010). The means of four permanent plots for cover and means of six samples for standing biomass per paddock were used for regression analyses. Cover and standing biomass/cover ratio of *Taraxacum* was log transformed to meet the assumption of ANOVA.

Results

There was a significant effect of treatment ($P < 0{\cdot}001$), year ($P < 0{\cdot}001$), and an interaction of treatment and year ($P < 0{\cdot}001$) on the cover of *Taraxacum* for the years 1998–2012. At the beginning of the experiment in May 1998 (before the different management treatments were imposed on the previously unmanaged grassland), there were no significant differences in the cover of *Taraxacum* among treatments and cover varied from 1·0 to 4·1% (Figure 1). Immediately following the onset of the different management treatments, it was evident that all types of defoliation treatments (ICG, IG, ECG, EG) supported an increase in the cover of *Taraxacum*. The lowest amount of cover was recorded in the unmanaged treatment (U) over the duration of the experiment, and since 2000, it has not exceeded 0·1%. Up to 2006, *Taraxacum* was especially promoted by the combination of cutting and subsequent grazing (ICG and ECG); however, the differences among all managed treatments were small. In 2007, there was a pronounced decrease of *Taraxacum* in all of the defoliation treatments, with no significant differences among treatments. The greatest decrease in the cover of *Taraxacum* was recorded in the ECG treatment (from 29 to 13%), followed by IG (from 24 to

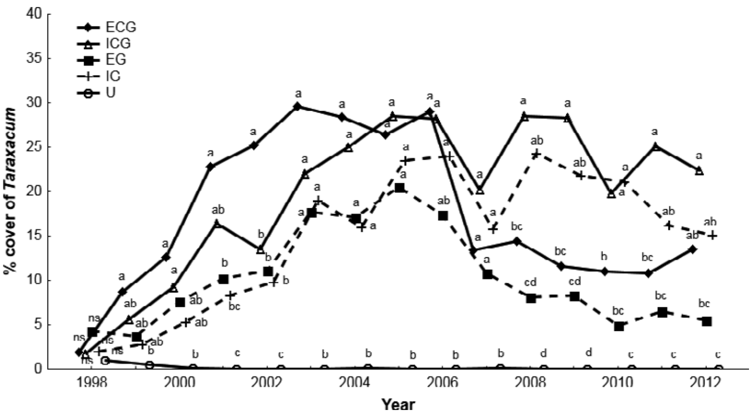

Figure 1 Changes in seasonal cover of *Taraxacum* under different treatments for the years 1998–2012. *P* represents probability value obtained by one-way ANOVA for each year, and $P < 0{\cdot}01$ was for analyses in years from 1999 to 2012. n.s. – non-significant result in year 1998. Significant differences ($P < 0{\cdot}05$) according to the Tukey's post hoc test are indicated by different letters. Treatment abbreviations are as follows: intensive grazing (IG), first cut followed by intensive grazing (ICG), extensive grazing (EG), first cut followed by extensive grazing (ECG) and unmanaged grassland (U).

16%), ICG (from 28 to 20%) and EG (from 17 to 11%). After 2007, the management intensity became a significant factor for *Taraxacum* cover in the years 2008–2012. This increase in *Taraxacum* cover according to grazing intensity was strengthened by the combination of cutting and grazing (ICG > IG > ECG > EG).

There was a significant ($P < 0{\cdot}001$) positive linear relationship between cover of *Taraxacum* and cover of *A. capillaris* ($r = 0{\cdot}312$), *Poa trivialis* ($r = 0{\cdot}354$) and *T. repens* (0·452). On the other hand, there was a significant ($P < 0{\cdot}001$) negative linear relationship between cover of *Taraxacum* and cover of *Aegopodium podagraria* ($r = 0{\cdot}359$), *Alopecurus pratensis* ($r = 0{\cdot}380$), *Galium album* ($r = 0{\cdot}392$) and *Holcus mollis* ($r = 0{\cdot}362$). Correlation coefficients of relationships between cover of *Taraxacum* and cover of other vascular plant species were lower than 0·3 or they were non-significant. A significant positive linear relationship between percentage cover and standing DM biomass of *Taraxacum* was found (Figure 2). The lowest standing biomass/cover ratio was recorded in the EG treatment, but this ratio was very similar for the other managed treatments (IG, ICG, ECG) with no significant differences among treatments (Figure 3). There was a significant negative linear relationship between percentage cover of *Taraxacum* and the mean actual sward height (Figure 4).

Discussion

The main message from the results obtained from this experiment is that the imposition of different long-term grassland management regimes on previously abandoned grassland resulted in significant divergence in the proportions of *Taraxacum* in the sward. We were able to distinguish two main periods, however. In the first 10 years of the study, any management regime, regardless of its intensity, was the key driver for the rapid development of *Taraxacum* presence relative to the unmanaged treatment, whereas in the last 5 years of the study, the grazing intensity was the key factor that affected the presence and amount of *Taraxacum.* The lowest proportion of *Taraxacum* was found in the abandoned treatment, and this occurred over the entire duration of the experiment. There was a tendency for the co-occurrence of *Taraxacum* with short growing species (*A. capillaris* and *T. repens*) and the taller grass *P. trivialis*. It seems that these species do not compete with each other and they share the same niche presented by intensive defoliation and disturbance by trampling. Generally, higher defoliation intensity under intensive grazing is more favourable for dandelion presence (Bakker *et al.*, 1983), especially in short sward-height patches (Ludvíková *et al.*, 2015). This is because the sparse canopy and light penetration into the base of the sward increase the possibility for seed germination and for plants to enter into the generative phase successfully (Mølgaard, 1977; Pykälä, 2005). Higher grazing intensity is also related to increasing grassland disturbance (Liu *et al.*, 2013), which supports the higher presence of gap frequencies (Bullock *et al.*, 1994) required for successful dandelion seed germination. On the other hand, intensive defoliation can increase tiller densities of grasses (Brock *et al.*, 1996) and thus reduce the introduction of *Taraxacum* because of the competitive ability of the existing

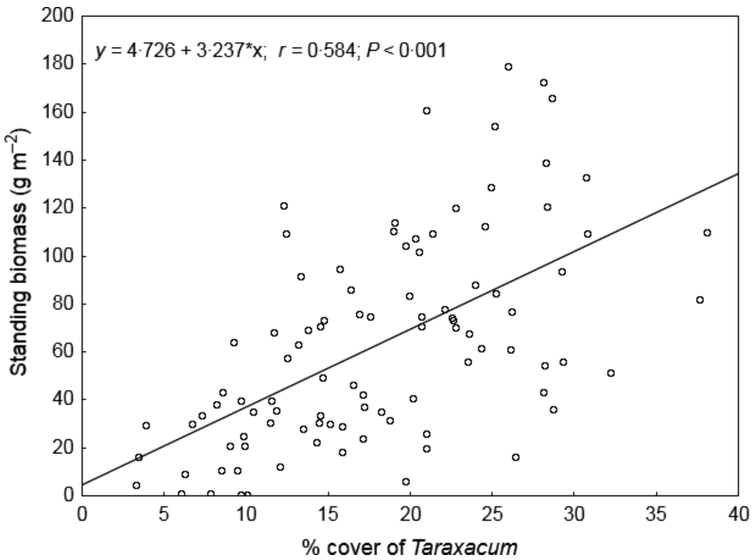

Figure 2 Relationship between percentage cover and standing DM biomass of *Taraxacum* over the years 2001–2012.

sward (Hoffmann *et al.*, 1997; Hofmann and Isselstein, 2004). However, these above-mentioned studies were based on species-poor grasslands that were dominated by *Lolium perenne*, with several times higher tiller density than in the *A. capillaris* grassland in our experiment (Pavlů *et al.*, 2006). Therefore even under intensive grazing in *A. capillaris* grassland, the tiller density of grasses in May was only about 3000–7000 tillers m^{-2} in May (Pavlů *et al.*, 2006). This tiller density was unlikely to have had an adverse effect in terms of restricting the introduction of forbs into the sward. Moreover, besides differences in the dominant grass species, the later start of the vegetation season can also contribute to a less dense sward, and at the site of our experiment the start of grazing season is usually in late April/early May because of the long duration with snow cover (Liberec Meteorological Station). In addition, sward disturbance by machinery during hay harvesting is very important for the successful spread of *Taraxacum* into grasslands.

Conditions that are favourable for the spread of *Taraxacum* include the combination of seed production and dispersal with the presence of open gaps caused by trampling or dung/urine patches or by disturbance due to cutting (heavy biomass crop, sward damage). Similar findings to our results were reported by Tarmi

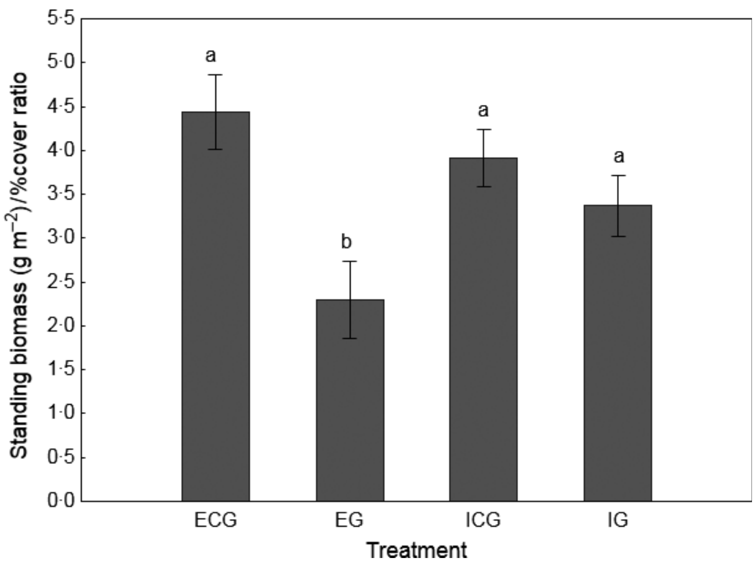

Figure 3 Standing DM biomass/cover ratio under different treatments over the years 2001–2012. Significant differences ($P < 0{\cdot}05$) according to the Tukey post hoc test are indicated by different letters. Treatment abbreviations (IG, ICG, EG, ECG) are explained in Figure 1.

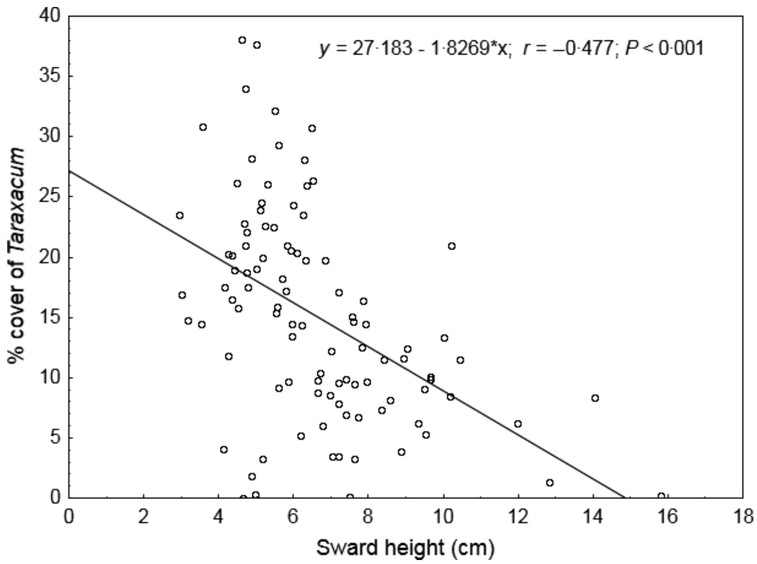

Figure 4 Relationship between percentage cover of *Taraxacum* and actual sward height during data collection over the years 1998–2012.

and Hyvönen (2012), who found that *Taraxacum* was abundant at sites where frequent cutting was applied. This suggests that cutting management in late May or early June, under the weather conditions of central Europe, can allow sufficient time for dandelion to flower and produce seeds. Therefore, the greater abundance of *Taraxacum* in treatments that are both cut and grazed, compared to treatments that are grazed only, can be ascribed to greater seed production (Abu-Dieyeh and Watson, 2007; Pavlů *et al.*, 2007). For this reason, early cutting before setting of ripe seeds seems an appropriate method of grassland management that will limit seed dispersal and the opportunities for subsequent germination of *Taraxacum* (Martinková *et al.*, 2009, 2011). Similarly, early cutting before the main period for seed production of *Taraxacum* was recommended by Neuteboom and Lantiga (1991) as a method for reducing dandelion without chemical control.

An unexpected finding was the marked decrease of cover of *Taraxacum* that was observed in all of the management regimes applied in 2007, the mid-period of the experiment. This decrease cannot be directly linked to unusual weather conditions, because there were no substantial changes in precipitation and temperature (Czech Hydrological Institute; www.chmi.cz), and no significant fluctuations in herbage biomass production under the OGE experiment were recorded during this period (Š. Supek, unpublished data).

Competition for light in the existing sward is one reason why *Taraxacum* plants were less abundant in the swards of extensively managed treatments than in intensively managed ones. The presence of lower proportions of dandelion under extensive grazing has also been described in a similar pasture experiment in Reliehausen (Germany). In that study, lenient grazing management resulted in a higher proportion of grass stems in the swards, and dandelion was less competitive due to its prostrate life form (Isselstein *et al.*, 2007). However, our experiment is the first study to reveal that extensive grazing leads not only to a reduction in the percentage cover of *Taraxacum* plants, but also in a reduced standing biomass/cover ratio. It means that, due to the effects of light competition in the existing sward, *Taraxacum* plants had lower fitness in extensively managed grassland than in intensively managed grassland.

Further, the results presented in this paper show clear evidence for the existence of linear relationships between cover and aboveground standing DM biomass of *Taraxacum* under experimental conditions of long-term pasture management. Although the existence of linear relationships between biomass and cover has been reported previously for temperate grassland vegetation (Röttgermann *et al.*, 2000; Axmanová *et al.*, 2012), this was not tested solely for dandelion plants. Therefore, measurement of the percentage cover of *Taraxacum* could be used as a simple method to indicate the standing DM biomass of *Taraxacum* in the sward.

Conclusion

On *A. capillaris* grassland, management with intensive grazing led to the greatest increase in abundance of *Taraxacum*. This effect was further strengthened if there was also previous cutting during the late-flowering phase. Conversely, cover of *Taraxacum* was negatively affected by increasing sward height where *Taraxacum* plants had lower fitness. Extensification management in *A. capillaris* grassland could therefore be used as a simple method for the control of *Taraxacum* abundance and reduce its seed production and dispersal to adjacent arable land in the vicinity of infested grasslands. Abandonment of grassland management would be expected to result in the strongest elimination of dandelion. This study emphasizes the importance of the decision-making process for grazing management in semi-natural grassland and its consequences for the control and development of *Taraxacum* species.

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