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Control of alpine dock (*Rumex alpinus*) by non-chemical methods

Trajnostno odstranjevanje alpske kislice (*Rumex alpinus*)

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Abstract: Alpine dock (*Rumex alpinus*) is a troublesome weed particularly in protected zones or Natura 2000 areas, in which only non-chemical control measures can be applied. The aim of our study was to investigate by means of a field experiment the effectiveness of various non-chemical methods: mowing, manual removal, heating, foil and grazing by cattle and pigs. Floristic changes, cover, number of shoots and biomass were monitored at 14-day intervals for three consecutive years. Manual removal and foil were most successful, with almost complete removal of the biomass and cover of alpine dock, and mowing, which reduced the cover to 50%. Other methods were not as efficient. Animals avoid grazing on *R. alpinus* and heat merely supresses dock growth for a short period.

Keywords: Slovenia, mountain pastures, agricultural management strategies, weed control, *Rumex alpinus*

Izvleček: Alpska kislica (*Rumex alpinus*) je problematičen plevel gorskih pašnikov, še posebej v zaščitenih območjih ali območjih Natura 2000, kjer lahko uporabimo le nekemične metode zatiranja. S poljskim poskusom smo testirali učinkovitost različnih nekemičnih metod odstranjevanja alpske kisice: košnjo, ročno odstranjevanje, toploto, folijo in pašo goveda oz. prašičev. V 14- dnevnih obdobjih smo tri vegetacijske sezone spremljali floristične spremembe, pokrovnost, število poganjkov in biomaso. Najbolj uspešni sta bili metodi ročnega odstranjevanja in folija, kjer smo biomaso in pokrovnost kislice skoraj popolnoma odstranili, s košnjo pa smo ju zmanšali za polovico. Ostale metode niso bile tako uspešne. Živali se izogibajo alpski kislici, z ožiganjem pa smo rast kislice zaustavili le za krajši čas.

Ključne besede: Slovenija, gorski pašniki, kmetijsko-upravljalske strategije, zatiranje plevelov, *Rumex alpinus*.

Introduction

Alpine dock (*Rumex alpinus* L.) is a perennial species consisting of a horizontal rhizome (and a root up to 300 cm long), above-ground vegetative shoots with three to five big leaves, and fertile stalks bearing smaller leaves and up to several thousand flowers and fruits (Kutschera and Lichtenegger 1992, St'astna et al. 2010). *R. alpinus* is a common plant species in all mountains of western, central and eastern Europe, including the Apennines, the mountains of the Balkan Peninsula and the Caucasus (Meusel et al. 1965). It builds species-poor monodominant stands and the cover of *R. alpinus* is often close to 100% (Kliment and Jarolimek 1995). The species is strongly nitrophilous and grows on nutrient-rich soils frequently near farm buildings. A high content of plant available potassium and nitrogen in soil favours *R. alpinus* (Bohner 2005). It can be regarded as a pasture weed, dominating and reducing valuable pasture areas. *R. alpinus* (as many grassland weeeds) has several harmful characteristics: low nutritive value, noxious (high oxalic acid content), avoided by animals, not suitable for conservation and high competitors occupying large areas (Bohner 2005, Dietl 1982, Vasas et al. 2015)

Docks (*Rumex* spp.) are very troublesome weeds in agricultural land in many countries, in arable crops or permanent grasslands (Jeangros and Nosberger 1990), for short period only (Niggli et al. 1993).

Non-chemical control of docks (*Rumex* spp.) has become important in recent years, mainly because of an increase in organic farming, and several non-chemical methods are applied: biological, mechanical and cultural. These consist of: frequent cutting, mechanical removal, heating, use of predators and parasites, grazing (Hejcman et al. 2014, Van Eekeren et al. 2006, Zaller 2004 and references cited there). The main aim is to hinder the build-up of seeds and weaken regrowth capacity by destroying biomass (Zaller 2004).

In addition to organic farming, agriculture in Natura 2000 areas (in lowlands and mountains) requires management practices that do not rely on the use of herbicides and are beneficial for the conservation of species, habitats and the environment. In mountainous areas, agriculture is mainly Alpine dairy farming, with the animals grazed over the summer. Mountain pastures include a significant fraction of the plant species pool of Alpine regions (Bätzing 1991), and well-managed pastures can support species-rich plant communities of high conservation value (Spatz 1975).

Mountain pastures were often not properly managed in the middle of last century. One threat is abandonment or low management intensity, which leads to secondary succession and overgrowing of areas with shrubs and trees. The other is intensification by inappropriate grazing practices or use of fertilisers, which results in eutrophication and weed invasion (Galvánek and Janák 2008). The latter is responsible for the invasion of nitrophilous plant species (and *R. alpinus* as the most significant) and communities, which can spread over large areas and are not useful as pastures and farmers are not entitled to subsidies from agri-environmental-climate packages within the current Slovenia's Rural Development Programme (Dular et al. 2013). Another impact of alpine dock spreading in protected areas is a reduction of species diversity and the endangerment of rare plants (St'astna et al. 2010).

The aim of our study was to investigate the use of various non-chemical methods on the control of *R. alpinus* in a mountain pasture under field conditions. To the best of our knowledge, only two field experiments for the control of *R. alpinus* have been set up without the use of herbicides, but with fewer methods applied (Corradini and Artigianelli 1991) or monitoring was done only for one season (Tsarik 1987).

Methods

Study site

The plot experiment was established in stands with 100% cover of *R. alpinus* on the high mountain pasture Korošica (northern Slovenia) at an elevation between 1500 m – 1570 m (46.434348 N, 14.291490 E). Korošica is a part of the Karavanke Natura 2000 area (SI3000285). There are 56 ha of pasture land on Korošica and, according to the state prescribed pasture grazing order, 80 animals (cattle and horses) or 65 LU can graze from mid-June till mid-September. Alpine dock has spread abundantly, presumably due to excess stock or the use of mineral fertilizers during the last ca. 20 years, and now occupies 9% of the grazing area (Dular et al. 2013).

The climate is cool and humid (Ogrin 1996). Average annual precipitation is 1680 mm (Podljubelj meteorological station), and average annual temperature is 3.6 °C (Krvavec meteorological station) (Anonymous 2014).

Grassland vegetation on Korošica is classified as *Homogyno alpinae-Nardetum* Mráz 1956 – mat-grass acidophilous pastures of submontane to supramontane belts of mountain ranges and is a priority habitat type (Annex I habitat type 6230).

Soil analysis was done before the set-up of the experimental plots in 2012. The analysis showed a strongly acidic soil (pH 4.2) with a low content of phosphorus (P: 20.18 mg/kg^{-1}) and sufficient content of potassium (K: 283.79 mg/ kg^{-1}). Soil samples were analysed by Agrochemical laboratory of the Agricultural Institute of Slovenia.

Experimental design

Testing of sustainable removal of *R. alpinus* on Korošica lasted three vegetation seasons (2012–2014). The removal experiment was set up as a random block on 4 x 4 m test plots (in 4 replicates) and two 10 x 15 m plots (in single versions). Various methods were tested: mowing, flaming, foil cover, manual removal and grazing (cattle and pigs).

For *Mowing*, *Heat*, *Foil* and *Manual*, we used four replicates, while *Cattle* and *Pigs* were only tested in the first year, and using a larger fence, because of the difficulty of using the animals (we were unable to set larger plots and the number of animals was limited) and the remote location of the Alpine dairy farm for transport. Heat treatment was done with an open flame and plants were flamed until foliage was burned down. Plots were mowed every 14 days (during the vegetation season), starting mid-June (2012), and the biomass was removed. Docks were manually excavated in the first year and the roots were collected and removed from the plots. Black polyethylene foil was installed permanently for two seasons. Animals were enclosed in the two larger plots: cattle grazing – 6 cattle / 2h a day / through the whole season and pigs rooting – 2 pigs for 4 weeks. In the case of pigs, we used the only autochthonous breed in Slovenia (Krškopolje pig), which is adapted to be kept outdoor.

After treatment of the plots, we sowed a commercial grass seed mixture (*Trifolium repens* 5%, *Phleum pratense* 16%, *Lolium perenne* 79%, a product of Semenarna (Ljubljana). Commercial seed mixture was used because site-adapted mixtures were not available.

Data collection

Vegetation was sampled according to the Braun-Blanquet (1964) method on 9 m^2 plots. Relevés were made prior to the start of management and at the end of every vegetation season, after the different removal treatments.

All data were sampled prior to the start of the experiment, except for biomass, and repeatedly at the end of every vegetation season. Above ground biomass was sampled on two subplots (0.5 x 0.5 m) within every sampling plot and only *R. alpinus* plants were cut. The biomass was air dried and then kept at 104 °C for 24^h and weighed. Every 14 days, the height, cover estimation and number of shoots were sampled on two 1 m^2 subplots. Cover was visually estimated in percentages. An individual shoot was defined as a group of leaves that clearly formed a separate shoot, although not necessarily from a different root.

Data analysis

All data were tested for normality and homogeneity of variance prior to testing the differences. ANOVA and Non-parametric tests were used in STATISTICA (StatSoft 2007).

The floristic composition was compared in a matrix (plots by species) arranged in JUICE (Tichý 2002). De-trended correspondence analysis (DCA) was done in Canoco (ter Braak and Šmilauer 2002). Species cover values in percentages were square root transformed.

Results

The association *Rumicetum alpini* Beger 1922 was fully developed before the experiment, with characteristic species *R. alpinus* and *Stellaria nemorum* dominating and with 100% cover of the site. Stands were species poor, with a few nitrophilous species (*Urtica dioica*) and species indicating of periodically wet soil being present (*Deschampsia cespitosa*, *Ranunculus repens*).

Changes in floristic composition differed among treatments. The greatest changes in species composition were in plots covered by foil and those subjected to manual excavation (Fig.

1). Dock plants were completely removed there and replaced with grassland species (*Lolium perenne*) from seed mixture. Changes were gradual on mowed plots, where species turnover was slower and alpine dock covered half of the plot after three years, although grasses were already developed. Other plots had a similar position on the DCA ordination graph, indicating smaller changes after treatments (Fig. 1).

The species number per plot after three years (results not shown) increased in all treatments except for *Foil* but the highest increase was on mown plots.

Comparisons within treatments showed significant differences in biomass between the first year and the following two for *Manual*, *Foil* and *Mowing*, while *Heat*, *Cattle* and *Pigs* did not differ from *Control* (Fig. 2).

Differences in biomass calculated for the last sampling year 2014 (one-way ANOVA, Bonferroni test) showed that *Heat, Cattle* and *Pigs* did not significantly differ from *Control* plots. The treatments *Manual*, *Foil* and *Mowing* were significantly different from *Control* but were not significantly different from each other.

Changes in the cover of *R. alpinus* within each treatment show a significant reduction of cover for *Manual* and *Foil*, while *Mowing* significantly reduced cover only after the second year (Fig. 3). *Pigs* were very successful in cover reduction but *R. alpinus* recovered in the third year because the treatment lasted for only one year. There was a similar result with the *Cattle* treatment.

The height of the dock plants was already significantly lowered by the *Manual* and *Foil* treatments after the first year, while *Mowing* reduced it only in the last sampling year (Fig. 4). Other removal treatments were not successful in that.

The height of plants was also very variable among sampling years, since this plant trait is related to seasonal climatic variables that differed during the experiment (e.g., very dry 2013 and wet 2014 season).

The number of shoots was significantly lowered by *Manual, Foil* and *Mowing* (Fig. 4). The number also varied among years, since sampling of particular shoots is very subjective, although it was done by the same observer.

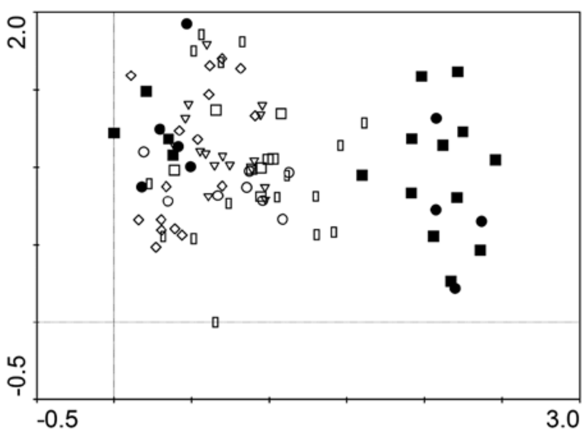

Figure 1: DCA analysis of vegetation plots. Eigenvalues for the first four DCA axes are 0.390, 0.171, 0.128 and 0.100, respectively. Foil-full circle, manual-full quadrat, mowing-rectangle, heat-triangle, control-diamond, pigs-empty circle, cattle-empty quadrat.

Slika 1: DCA analiza vegetacijskih ploskev. Lastne vrednosti prvih štirih osi so 0,390, 0,171, 0,128 in 0,100. Folija: poln krog, ročno odstranjevanje: poln kvadrat, košnja: pravokotnik, toplota: trikotnik, kontrola: diamant, prašiči: prazen krog, govedo: prazen kvadrat.

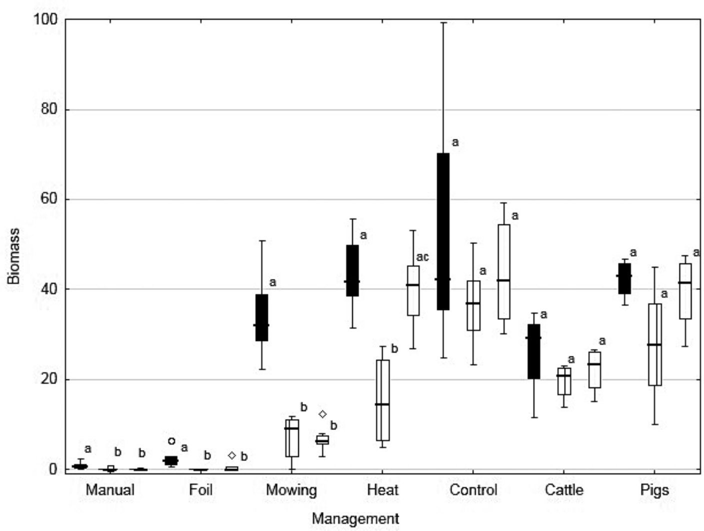

Figure 2: Box plot of biomass of *R. alpinus* on plots with different management in three consecutive years. Means with the same letter are not significantly different from each other (one-way ANOVA, P<0.05).

Slika 2: Škatla z brki biomase alpske kislice na ploskvah z različnim načinom zatiranja v treh zaporednih letih. Povprečja, označena z isto črko, med seboj niso statistično značilno različna (eno-fakorska ANOVA, P<0,05).

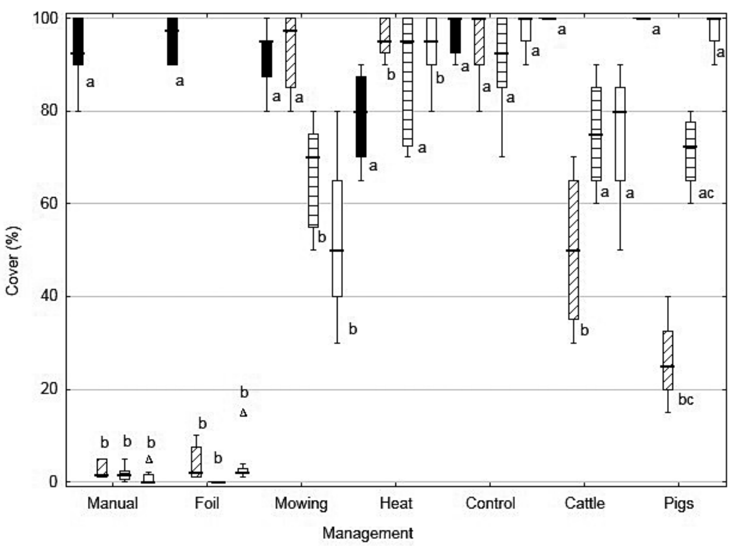

Figure 3: Box plot of cover of *R. alpinus* on plots with different management in three consecutive years. Means with the same letter are not significantly different from each other (one-way ANOVA, P<0.05).

Slika 3: Škatla z brki pokrovnosti alpske kislice na ploskvah z različnim načinom zatiranja v treh zaporednih letih. Povprečja, označena z isto črko, med seboj niso statistično značilno različna (eno-fakorska ANOVA, P<0,05).

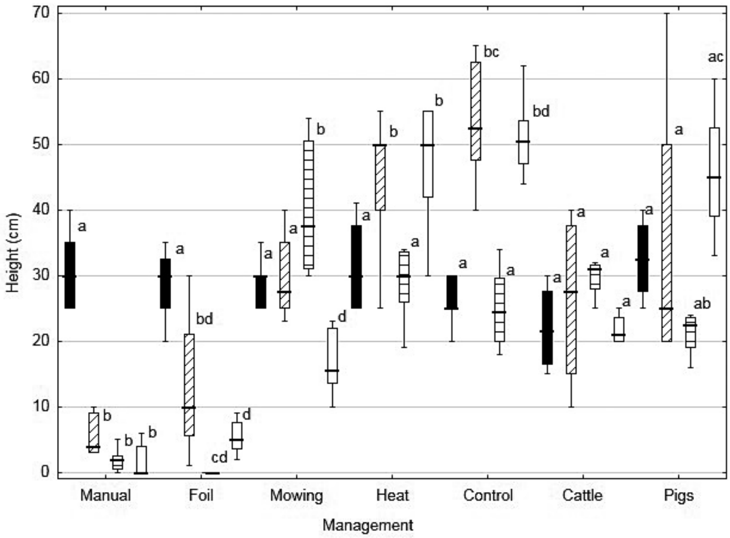

Figure 4: Box plot of height of *R. alpinus* plants in plots with different management in three consecutive years. Means with the same letter are not significantly different from each other (one-way ANOVA, P<0.05).

Slika 4: Škatla z brki višine alpske kislice na ploskvah z različnim načinom zatiranja v treh zaporednih letih. Povprečja, označena z isto črko, med seboj niso statistično značilno različna (eno-fakorska ANOVA, P<0,05).

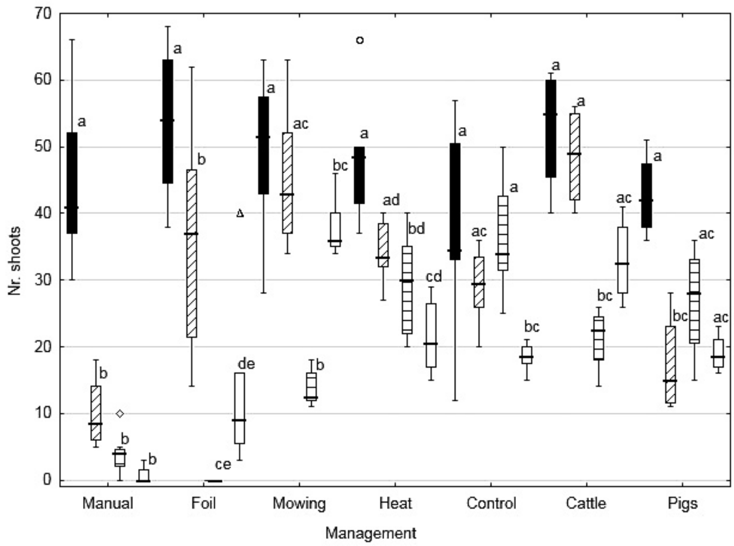

Figure 5: Box plot of number of shoots of *R. alpinus* in plots with different management in three consecutive years. Means with the same letter are not significantly different from each other (one-way ANOVA, P<0.05).

Slika 5: Škatla z brki števila poganjkov alpske kislice na ploskvah z različnim načinom zatiranja v treh zaporednih letih. Povprečja, označena z isto črko, med seboj niso statistično značilno različna (eno-fakorska ANOVA, P<0,05).

Discussion

Most research interest in floristic changes related to various management techniques has been oriented into changes of semi-natural grasslands in lowlands after changes in management or its cessation, and the impact of other *Rumex* species (*R. obtusifolius* and *R. crispus*). Studies dealing with *Rumex* spp. are in general dedicated to the removal of docks and less with the species composition of the plant community they invade. The only study monitoring floristic changes was made by Corradini and Artigianelli (1991).

Re-sowing of grasses was important to establish a new plant community and to prevent *R. alpinus* from growing again and to suppress its competitive ability. It is known that the seed bank has a limited role in the restoration of degraded sites (Handlova and Munzbergova 2006). The use of autochthonous seed mixtures of potential vegetation types or use of hay from an identical plant community would facilitate the succession but they were not available.

Although docks are troublesome weeds in grasslands, most control studies have been done on "lowland" species, e.g., *R. obtusifolius* and *R. crispus* (Van Eekeren et al. 2006, Zaller 2004). In addition, studies about alpine dock have often been partial, using particular methods (also chemical), or short term (see St'astna et al. 2010).

The largest reduction of *R. alpinus* was achieved by mowing, foil covering and manual excavation. Regular and frequent mowing has already been reported to influence *R. alpinus* (Corradini and Artigianelli 1991, Hujerova et al. 2013, St'astna et al. 2010, Tsarik 1987). The frequency of cutting is the most important and, not surprisingly, the more frequent the cutting the more effective is the dock suppression. In our study, we used cutting every 14 days since this period has already been shown to be effective (Tsarik 1987, Zaller 2004). The reduction of cover and biomass by mowing was very gradual compared to foil and excavation. This is congruent with the findings of Courtney (1985) that even five to seven cuts reduced the abundance of dock by only 60 %. When stands are mown less frequently, seedling emergence and seedling survival until next year increases (Tsarik 1987). Nevertheless, successful suppression is possible through regular mowing and removal of the biomass (Zaller 2004), although not in a short time (Pignatti and Pignatti 2014). Combination of mowing and grass seeding proved to be successful, which is congruent with the findings of Corradini and Artigianelli (1991). The competition of grasses and herbs is not enough to restrict docks in the long term (Zaller 2004) and should be combined with some other management. It is important to cut dock at a height of 10 cm to enable other plants to regenerate faster than *Rumex*.

Excavation successfully removed dock plants but it is a very time consuming method. Tillage is usually applied as the ultimate non-chemical control measure on heavy *Rumex* infestations on arable land, and also on grassland, although contrasting results are reported (see review by (Zaller 2004). We removed the upper soil layer with roots and since the rhizomes usually grow at a depth of up to 5 cm (Klimes 1992) or, less frequently, between 10-12 cm (Kliment and Jarolimek 1995), the removal of alpine docks was successful. It is necessary to remove and destroy the roots so they cannot regenerate. New plants can germinate from the remains of root fragments and from the seed bank (Tsarik 1987), so sowing grasses is important in order to suppress young plants that emerge. After three years, only a few small plants were present in the plots, identical to the results of Bucharová (2003), although she used herbicide.

The use of foil (or any other covering material) to reduce the light to weeds or any other invasive species is common practice (Bond and Grundy 2001) and it has been successfully applied to *R. alpinus* (Bechtold and Machatschek 2011). Light availability is a crucial resource in *R. alpinus* stands and control through competition for light should be successful (Zaller 2004). After one year, the docks are destroyed because of light reduction and high temperatures under the foil in the summer period. Foil is less suitable for large areas, especially in mountains with unfavourable climatic conditions.

Treatment with flame reduced the biomass but not the cover and the docks regenerated after the first year. Flame has been successfully used in dock infested grasslands but only on locally infested spots and on single plants (Pötsch 2003), while this method was less suitable in large patches of *R. alpinus,* similar to results in *R. obtusifolius*

(Zaller 2004). In the case of large patches, all plants were damaged by the heat and the herbs were unable to compete with the docks.

Rumex species are rarely grazed by animals and alpine dock is avoided by cattle and horses but readily eaten by goats (Bohner 2005, Ellenberg 1996, Hejcman et al. 2014) and has been used as pig fodder in the past (Wendelberger 1971). In our study, we used cattle and pigs for only one season and this resulted in some suppression of the alpine dock cover but probably more as a result of cattle trampling and tillage by pigs than grazing. Trampling can also reduce the *R. alpinus* above ground biomass (Tsarik 1987). Goats and sheep or combined with cattle graze on docks and effectively remove plants from grasslands (Hejcman et al. 2014) but in the case of mountain pastures in SE Central Europe, grazing of sheep and goats is not common or is traditionally limited to certain localities (part of NW Julian Alps) and the introduction of new animals would require a change in grazing policy related to NATURA 2000.

We must also stress that all grazing experiments from the literature were made in grasslands in which docks are scatter distributed, while alpine dock forms large monodominant stands and such patches are even more avoided by grazing animals.

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