

Mechanical weeding of *Rumex obtusifolius* L. under different N, P and K availabilities in permanent grassland

L. Strnad¹, M. Hejzman^{1,2}, V. Křišťálová¹, P. Hejzmanová³, V. Pavlů^{1,2}

¹Department of Ecology, Faculty of Environmental Sciences, Czech University of Life Sciences, Prague, Czech Republic

²Crop Research Institute, Prague, Czech Republic

³Department of Forest Management, Faculty of Forestry, Wildlife and Wood Sciences, Czech University of Life Sciences, Prague, Czech Republic

ABSTRACT

In Europe, *Rumex obtusifolius* L. is the most problematic grassland weed species, especially under the conditions of organic farming. The aims of this study were (1) to investigate the effectiveness of repeated mechanical weeding of *R. obtusifolius* from the permanent sward, cut two or three times per year, by digging the plants out from 5 cm below the soil surface, and (2) to test the effect of nutrient availability on the effectiveness of mechanical weeding. In 2007, the manipulative experiment was established on permanent grassland infested by *R. obtusifolius* using the following fertilizer treatments: control, P, N, NP and NPK. Plants of *R. obtusifolius* were removed eight times during three vegetation seasons. No significant decrease in the density of *R. obtusifolius* was recorded after three vegetation seasons and density was not significantly affected by fertilizer treatment. The cover of *R. obtusifolius* decreased slightly, but significantly, over the study period from 7.5% to 4.5%. The cover of *R. obtusifolius* was only marginally affected by fertilizer treatment. Mechanical weeding by digging the plants out from 5 cm below the ground is not a sufficient method of control for *R. obtusifolius* in infested fertile grasslands, even when applied eight times during three vegetation seasons.

Keywords: broad-leaved dock; fertilizer experiment; nitrogen; phosphorus; potassium; plant cover and density; weed control

Rumex obtusifolius L. (broad-leaved dock) is a common and troublesome weed in temperate grasslands because of its high seed production, persistent soil seed bank and its high ability to regenerate from fragmented underground organs (Cavers and Harper 1964, Hongo 1989, Niggli et al. 1993, Honěk and Martinková 2002). In the system of organic farming, infestation of grasslands by *R. obtusifolius* is a serious problem as it cannot be controlled by herbicides and it markedly reduces grass yield and overall quality of forage (Hejduk and Doležal 2004, Gebhardt et al. 2006, Pötsch and Griesebner 2007, Van Evert et al. 2009). For farmers in many countries, the fear of infestation of grasslands by *R. obtusifolius* is one of the most important obstacles preventing them from switching from conventional to organic farming (Zaller 2004, Hiltbrunner et al. 2008).

According to Zaller (2004), the methods of non-chemical control of *R. obtusifolius* in grasslands can be divided into biological, cultural and mechanical. Biological methods include the use of insects, for example *Gastrophysa viridula* is the most frequently used (Hatcher and Paul 2000, Honěk and Martinková 2004), and pathogenous fungi, especially *Uromyces rumicis* (Keary and Hatcher 2004). However, although biological methods have been investigated for decades, their practical use is still problematic. Cultural methods generally focus on prevention of infestation by creation of a dense, vigorous and competitive sward under optimal nutrient availability (Novak and Slamka 2003, Zaller 2004, Martinková et al. 2009). Mechanical methods for *R. obtusifolius* control have changed little over the years and are dominated by research into the effects of defoliation intensity and frequency under

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different N supplies (Niggli et al. 1993, Hopkins and Johnson 2002, Zaller 2006a, Stilmant et al. 2010), pulling it out by hand (Bond et al. 2007) and on the motorized milling of roots which seems to be the most effective method so far (Pötsch and Griesebner 2007).

It is well known that besides enormous seed production, *R. obtusifolius* is able to regenerate via buds on strong underground stem systems above the root collar (Pino et al. 1995). Buds are common on dock crowns in the upper 0–10 cm soil layer; it means that digging the plants out from less than 10 cm below the soil surface is not a very effective method of *R. obtusifolius* control. Bond et al. (2007) investigated the regeneration of *R. obtusifolius* from underground organs left in situ after the removal of plants at different depths. After 21 weeks, there was a 60% regeneration of plants that had been cut at 1 cm, 25% regeneration of plants cut at 5 cm and no regeneration from plants cut at the depth of 10 or 15 cm. According to Dierauer (1993), cutting at a depth of 5 cm gave 73% regeneration while cutting at a 10 cm depth gave 20% regeneration of *R. obtusifolius* plants. Whether digging the plants out from 5 cm below the ground surface several times during the vegetation season is a sufficient method for *R. obtusifolius* control still remains unsolved. Furthermore, one of the factors that enables spreading of *R. obtusifolius* into grasslands is a high nutrient availability, since *R. obtusifolius* was considered by Grime et al. (1988) to be nitrophilous and its competitive ability in grass-dominated swards increased substantially under high NPK availability in the soil (Haggar 1980, Niggli et al. 1993, Humphreys et al. 1999, Hopkins and Johnson 2002).

The aims of this study were therefore to answer following questions:

(1) Is digging the plants out from 5 cm below the ground several times during three consecutive vegetation seasons a sufficient method for *R. obtusifolius* control?

(2) Is there an effect of N, P and K availability on the effectiveness of this mechanical weeding?

MATERIAL AND METHODS

Study site. The fertilizer experiment was set up near the Mšec village, 45 km northwest of Prague (50°12'24"N; 13°51'40"E). The study site is a flat meadow with a mean annual precipitation and temperature of 550 mm and 8°C, respectively. The meadow had been cut two or three times per

year and occasionally fertilized with farmyard manure before establishment of the experiment. The altitude of the study site is 490 m a.s.l. The soil of the study site was classified as Pararendzina (syn. Calcic Leptosols). *Dactylis glomerata* (visually estimated cover of 45%), *Festuca arundinacea* (12%), *Phleum pratense* (9%) and *Taraxacum* sp. (8%) were the dominant species before establishment of the experiment. In the upper 10 cm soil layer the pH (H₂O) was 6.4, concentrations of plant-available (Mehlich III) P, K, Ca and Mg were 152, 267, 1688 and 171 mg/kg, respectively, and the content of total (Kjeldahl) N was 0.23% before the start of the experiment.

Experimental design. The experiment was established on a meadow infested by *Rumex obtusifolius* in the summer of 2007 and was arranged in four completely randomized blocks, each with five fertilizer treatments (20 plots altogether, Figure 1): (1) unfertilized control (C); (2) application of phosphorus (P); (3) nitrogen (N); (4) N and P (NP) and (5) N, P and potassium (NPK). The application rates for N, P and K in each dressing were 150 kg N/ha, 40 kg P/ha and 100 kg K/ha, respectively. The first fertilizer application was performed on the 19th August 2007. In 2008 and 2009, fertilizer was applied in the beginning of March and then after the first cut in June. Therefore, the total annual application of N, P and K in 2008 and 2009 was 300 kg N/ha, 80 kg P/ha and 200 kg K/ha, respectively. The area of each individual monitoring plot was 4 m × 3 m.

In 2008 and 2009 the experimental plots were cut twice each year - at the beginning of June and in August. In the first year of the experiment (2007), the second cut was done on the 19th August and the third cut was on the 22nd September. The stubble height in each cut was 5 cm.

Mechanical weeding of *R. obtusifolius* was performed manually with a hoe. All present *R. obtusifolius* plants were dug out at the depth of 5 cm below ground on the following dates: 19th August 2007, 22nd September 2007, 10th June 2008, 7th August 2008, 11th October 2008, 21st April 2009, 16th September 2009 and the 29th October 2009.

Data collection. The number of all *R. obtusifolius* plants (growing points according to Pino et al. (1995), individual plants or seedlings together) was counted in each monitoring plot on each day of mechanical weeding, which was performed eight times during the study period. The collected data were recalculated and expressed as plant density per 1 m² in all analyses.

The cover of *R. obtusifolius* was visually estimated, directly in percentage, in individual plots before



Figure 1. Aerial photograph of the *Rumex* experiment taken in May 2008 (photo M. Hejzman[©]). Plot abbreviations: the first digit indicates the number of the randomized block, the second digit indicates the number of the individual plot, C is unfertilized control, N, P, NP and NPK indicate the individual fertilizer treatments

each cut. The cover estimation was performed five times during the study period.

Data analysis. Repeated measures ANOVA was used to evaluate the plant density and cover data. One-way ANOVA followed by a post-hoc comparison using the Tukey HSD test were then applied to identify significant differences among treatments for plant density and cover of *R. obtusifolius* on each weeding day. The blocks were treated as a random factor. Linear regression was used to evaluate the relationship between plant density and cover and its temporal trends during the study period. All analyses were performed using the STATISTICA 8.0 software (StatSoft, Tulsa, USA).

RESULTS

The mean density of *R. obtusifolius* plants was 1.4 and 0.8 individuals per m² at the start and at the end of the experiment, respectively. As calculated by linear regression, no significant decrease in the density of *R. obtusifolius* was recorded during the experiment (Figure 2a). As calculated by repeated measures ANOVA, the effect of time on the density of *R. obtusifolius* was significant ($F = 6.34$; $P < 0.001$), but the effects of treatment ($F = 1.00$; $P = 0.447$) and the interaction between treatment and time ($F = 0.68$; $P = 0.869$) were not significant.

This indicates fluctuations in the density of *R. obtusifolius* during investigated period, but no change in the density due to fertilizer treatment. As calculated by one-way ANOVA, the effect of treatment was not significant on either of the individual sampling dates (Figure 2b).

The mean cover of *R. obtusifolius* plants was 7.5% and 4.5% at the start and at the end of the experiment, respectively. As calculated by linear regression, a significant decrease in the cover of *R. obtusifolius* was recorded during the experiment (Figure 3a). As calculated by repeated measures ANOVA, the effect of time on the cover of *R. obtusifolius* was significant ($F = 5.87$; $P = 0.007$), but the effects of treatment ($F = 2.05$; $P = 0.156$) and the interaction between treatment and time ($F = 1.036$; $P = 0.441$) were not significant. As calculated by one-way ANOVA, the effect of treatment was not significant on either of the individual sampling date (Figure 3b).

The cover of *R. obtusifolius* was significantly and positively dependent on its density (Figure 4).

DISCUSSION

The main observation of this study was that no significant decrease in the density of *R. obtusifolius* was recorded after the three seasons of mechanical weeding by digging the plants out from a depth of

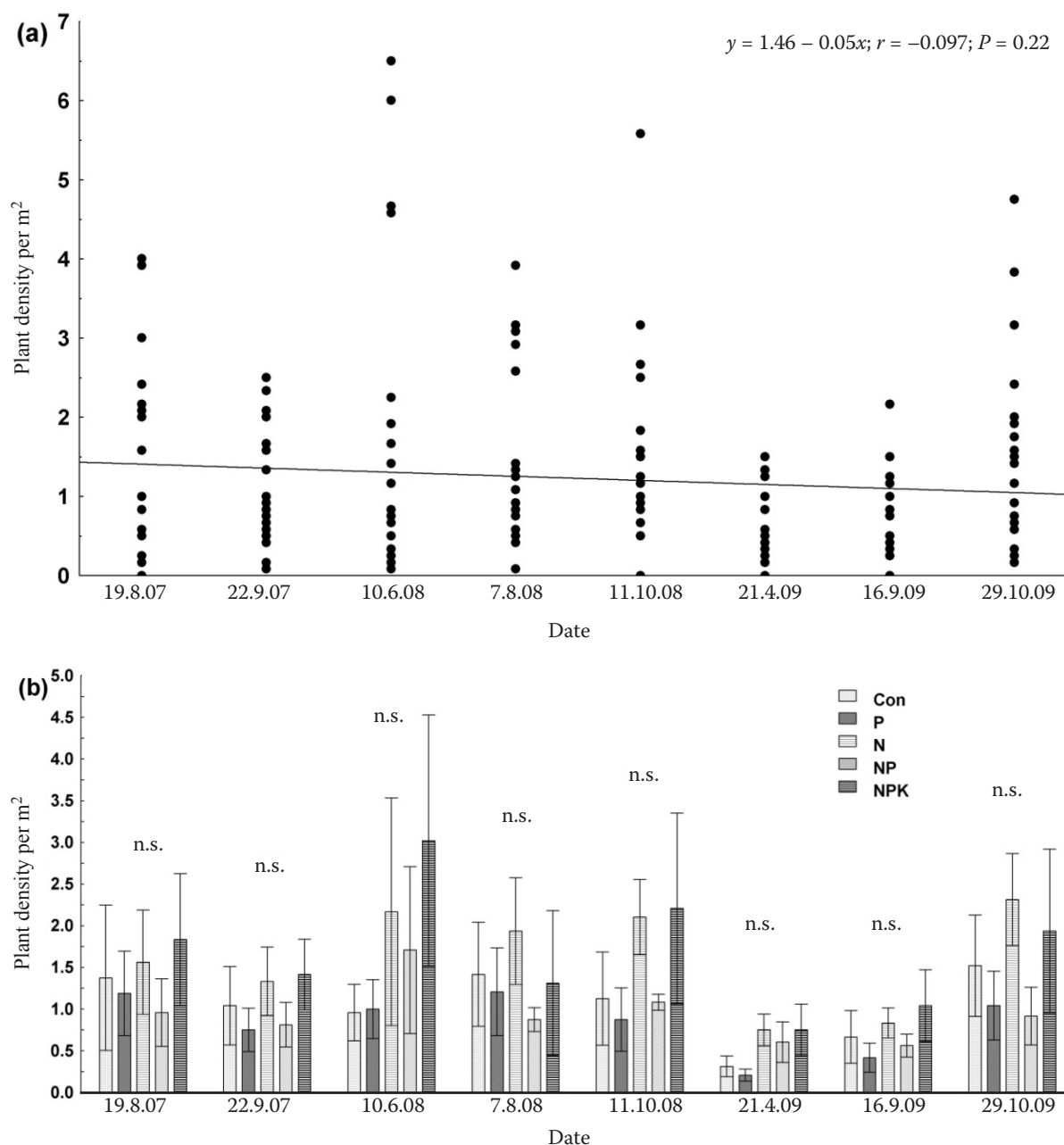


Figure 2. (a) Plant density of *Rumex obtusifolius* as a function of sampling date and (b) effect of treatments on mean plant density of *R. obtusifolius* on each individual sampling date. Error bars represent standard error of the mean (SE). Abbreviations: Con – unfertilized control; P, N, NP, NPK – fertilizer treatments; n.s. – result of one-way ANOVA was not significant

5 cm below the soil surface. The slight decrease in density from 1.4 on 0.8 individuals per m² after mechanical weeding performed eight times during the study period indicates that the investigated method was not sufficient for the control of a well-established population of *R. obtusifolius* in permanent grassland. Furthermore, no significant effects of fertilizer treatment on the effectiveness of mechanical weeding indicate that regeneration of *R. obtusifolius* after digging out is not affected by an increase in N, P or K supply. The low effectiveness

of mechanical weeding was caused by (1) high regeneration of the plants from underground organs and, in several cases, by (2) recruitment of seedlings from the soil seed bank, recorded in places where the sward was damaged by digging. The high regeneration (73%) of *R. obtusifolius* from underground organs cut at 5 cm below the soil surface was also reported by Dierauer (1993). On the other hand, Bond et al. (2007) recorded regeneration of only 25% of plants cut at the same depth. A new finding of this study is that high

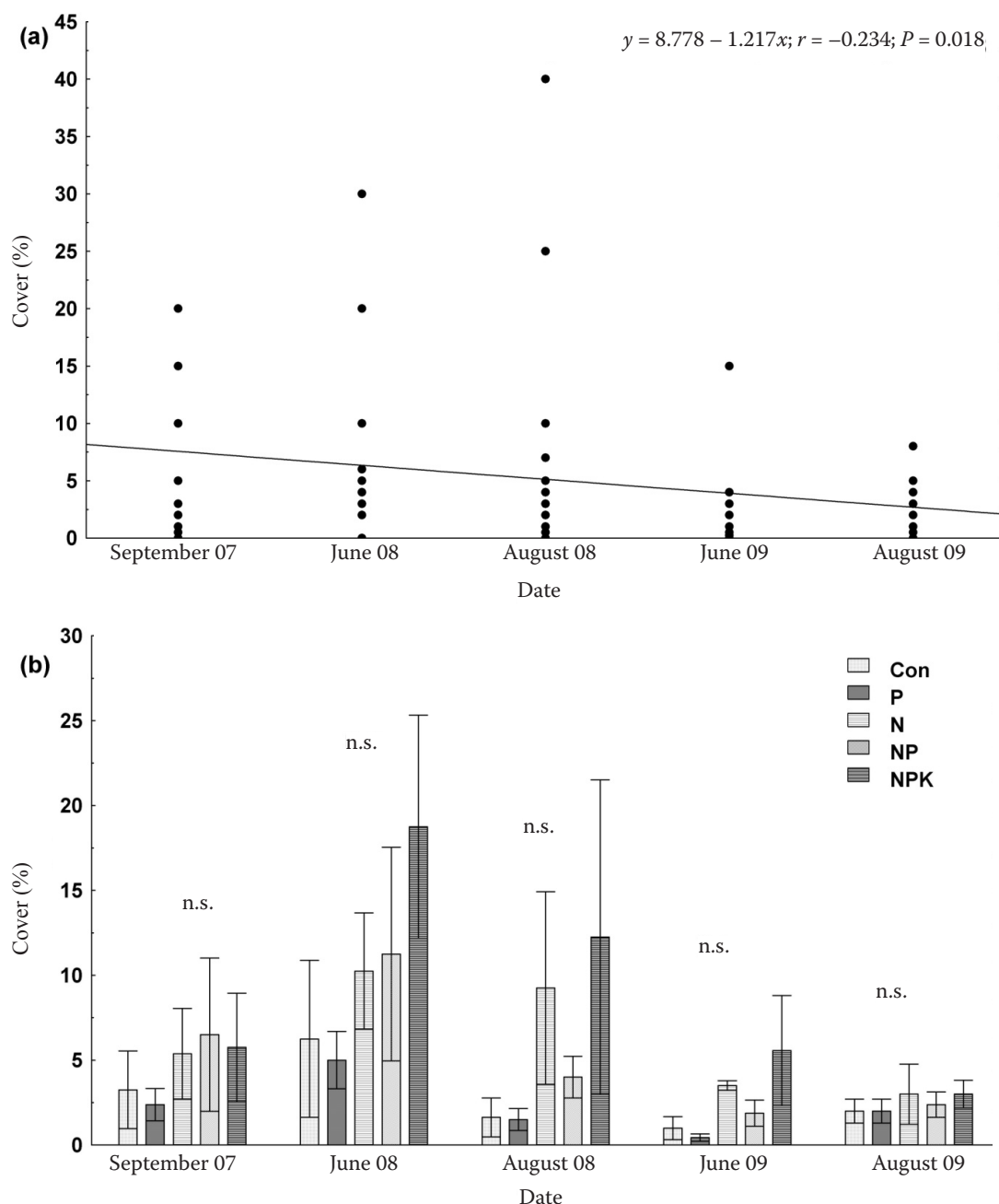


Figure 3. (a) Cover of *Rumex obtusifolius* as a function of sampling date and (b) effect of treatments on mean cover of *R. obtusifolius* on each individual sampling date. Error bars represent standard error of the mean (SE). Abbreviations: Con – unfertilized control; P, N, NP, NPK – fertilizer treatments; n.s. – result of one-way ANOVA was not significant

regeneration of *R. obtusifolius* from underground organs cut 5 cm below the soil surface can be recorded even in the case of repeated weeding. Although mechanical weeding was not able to fully eradicate *R. obtusifolius* from the grassland, it was probably able to prevent its predominance over grasses, especially in treatments with N application. This is clear from the cover of *R. obtusifolius*, which was relatively low in all of the treatments. An increase in the competitive ability of *R. obtusifolius* over grasses was frequently recorded under high

N application rates (Niggli et al. 1993, Hatcher et al. 1997, Hopkins and Johnson 2002). There was no effect of N, P and K supply on the regeneration of *R. obtusifolius* because during regeneration sufficient amounts of carbohydrates are stored in the taproot; therefore the nutrient supply is not important (Hidaka 1973). The low effect of P and K application on the growth of *R. obtusifolius* can be explained by the optimal P and K availability in the soil before establishment of the experiment. The concentrations of plant-available (Mehlich III)

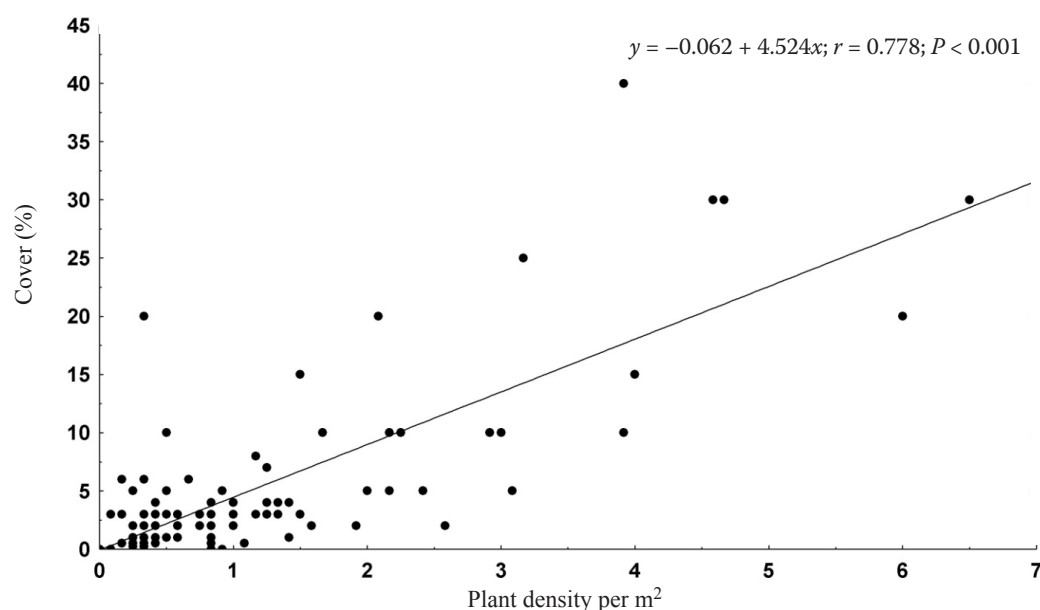


Figure 4. Cover of *Rumex obtusifolius* as a function of *R. obtusifolius* plant density

P and K were 152 mg/kg and 267 mg/kg in the upper 10 cm soil layer, respectively. These values are considered to be optimal for crops with a high P and K demand (Kulhánek et al. 2009, Madaras and Lipavský 2009), and for highly productive grasslands (Hrevušová et al. 2009).

The seedlings of *R. obtusifolius* were not counted separately as it was difficult to distinguish between seedlings and plants regenerating from underground organs. Despite this, several seedlings were positively determined according to their primary leaves in the studied plots. Although *R. obtusifolius* can be quickly renewed by seedlings originating from the soil seed bank (Hunt and Harkess 1968), the low effectiveness of mechanical weeding in this study was caused more by the regeneration of plants from underground organs than by seedling emergence. Seedlings were strictly recorded only in gaps created by weeding. The low density of the seedlings was also clear from the relationship between plant density and cover of *R. obtusifolius* (Figure 4), since a high density of plants was never recorded under low cover. This indicates that *R. obtusifolius* has a low competitive ability as a seedling, and can hardly establish in closed grassland communities (Weaver and Cavers 1979). Furthermore, the germination of seeds was probably negatively affected by the allelopathic effect of mature *R. obtusifolius* plants, as reported by Zaller (2006b).

The low effectiveness of mechanical weeding was recorded under the management regime of only two or three cuts during the study period, but it

is likely that a slightly higher effectiveness could be expected under very high cutting frequencies since Courtney (1985) recorded a reduction in *R. obtusifolius* abundance by 60% in a grassland cut 5–7 times per season over a total of 6 years.

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Corresponding author:

Doc. RNDr. Michal Hejčman, Ph.D., Česká zemědělská univerzita v Praze, Fakulta životního prostředí, Katedra ekologie, Kamýcká 1176, 165 21 Praha 6-Suchbát, Česká Republika
phone: + 420 224 382 129, e-mail: hejcmam@fzp.czu.cz
