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Weeds and weed control as factors for game damage to and growth of Norway spruce (*Picea abies* (L.) Karst.) and European beech (*Fagus sylvatica* L.)

Michal Bureš [1], Petr Čermák [1]

Keywords: *weed, browsing, competitiveness, height growth, treatments, Picea abies, Fagus sylvatica*

Abstract

This research aims to determine the effect of weed management intensity and browsing by wild, even-toed hoofed mammals and on the growth of young trees in selected areas in the highlands of Drahanská vrchovina, the Czech Republic. Measurements were carried out in the stands of Norway spruce (*Picea abies*) and European beech (*Fagus sylvatica*) on an extensive forest clearing after a major wind throw (wind calamity). Treatments were applied to the area to control weeds (mowing and herbicide spraying) in various degrees of intensity (total, strips, spot). For comparison, a control area was left without any action against weeds. Height and thickness growth, mortality, and presence of game damage were recorded across the experiment. A rather high ground cover of weed (50%+) significantly slowed growth. Surprisingly,

[1] Lesnicka a Drevarska Fakulta, Mendelova Univerzita v Brne, Zemedelská 3, Brno 613 00
Corresponding author: Michal Bureš (mich.bures@seznam.cz)

more frequent damage by game was encountered on areas with a greater presence of weeds. For beech, the results were not clear in terms of growing bigger. A significant extent of browsing was located on areas where there was less weed, i.e. areas with total treatment. Here, the positive influence of visibility of seedlings on the higher rate of browse was attested. The mortality was also more pronounced in areas with treatment carried out.

1. Introduction

Regeneration of a forest stand is dependent on the ability of tree seedlings to survive and resist the competition from the neighbouring plants (BROWN et al 1998). The colonisation by weeds is often gradual, but after 2-3 years the area can be completely overgrown by grasses - which under this country's circumstances generally includes *Deschampsia flexuosa* and *Calamagrostis arundinacea*, and herbs - *Rubus idaeus* and *Chamaenerion angustifolium* with ferns - *Pteridium aquilinium*. On the regenerated areas, mutual competition of aerial vegetation may affect soil moisture, the space for the roots of trees, the nutrient content, light penetration and soil temperature, thus reducing the growth and success of the seedlings (GJERSTAD et al. 1984; WALSTAD & KURCH 1987; GROSSNICKLE & HEIKURINEN 1989).

The influence of weeds is thought to affect seedling growth in two ways, the first effect is the negative impact of competition for light, water, and nutrients on the growth and survival of woody species, potentially leading to increased mortality (e.g. KESSL et al. 1957; POSARIĆ 2010; LÖF & WELANDER 2004; SWEENEY et al. 2002; BURDETT 1990; NILSSON & ORLANDER 1995). In such cases, reduction of aerial vegetation is necessary for the required growth of woody species (e.g. MARGOLIS & BRAND 1990; COATES et al. 1991). The second effect is that an adequate level of weed competition may lead to the positive effect on growth if certain other pre-conditions are met. Woody plants strive for the earliest possible acquisition of competitive advantage through the apical dominance (ČERMÁK et al. 2011), thus exhibiting an increased height increment. The presence of weed may also lead to reduced damage by browsing through increasing food supply and partially hiding the young trees from game.

Availability of water in soil is a limiting factor affecting the relationship between weeds and the growth of woody species. A number of studies have concluded that stress due to lack of water is the factor that most limits the growth of woody plants (CONARD & RADOSEVICH 1982; SANDS & NAMBIAR 1984; COLE & NEWTON 1986; PETERSEN et al. 1988). Newly planted seedlings are particularly vulnerable because of their root distribution is limited when compared with seedlings originating from natural regeneration (BURDETT 1990). Suppression of unwanted vegetation is done through either site preparation prior to planting operations or chemical control through the use of herbicides; mowing after planting is also an option. Reducing competition for water with caused by other ground vegetation can then initiate an increase in growth of the target species (e.g. BÄRRING 1967; MARGOLIS & BRAND 1990; COATES et al. 1991). For instance, NILSSON et al (1995) found lower growth and higher mortality of seedlings in control areas without weed control in comparison to treated areas just during dry periods; this occurred on areas newly afforested with spruce in Sweden.

In the Czech Republic, while conventional manual mechanical treatment - mowing - still prevails (around 60% of the area), the extent of treatment by a brush cutter is gradually on increase, whether it is total or stripe-wise treatment, up to 20% of the area. Treatment of areas using herbicides has also increased by 10% approximately over the past 20 years; in 2002 it was about 9%, and in 2009 it was about 20% (CUDLÍN 2009). In connection with these changes, solution of problems with proportionality and necessity of spot control methods as well as assumption of the benefits and drawbacks of these methods is very important (ČERMÁK et al 2011).

Another important question is whether young trees in areas with reduced weeds exhibit the same compensatory growth behaviour (in reaction to the ungulate browsing) as in areas with weed not reduced. KESSL (1957) found that if there was browsing damage in woody species which were simultaneously exposed to the impact of denser and higher weed (more heavily weeded areas with no treatment), the mortality of these was higher than on areas treated against weed. However, other studies show that apart from the influence of weed competition, easy visibility of seedlings by browsing animals, the ease of movement on treated and untreated areas and the total amount of available food for browsers can play an important role. The areas with present weed can thus be damaged to the lesser extent, in some cases, than those with suppressed weed, particularly for heavy total treatment (ČERMÁK et al. 2011).

Our basic hypothesis for the present study was: (i) total treatment to control weed can lead to increased damage by browsing that outweighs, through its impact on the growth of woody plants, the negative effects of competition from weed; (ii) the competition from weed may be compensated of positive effect, for example, by shading on extremely hot days.

2. Materials and methods

2.1 Study sites and experiment design

The research was conducted in the highlands of Drahanská vrchovina north-east of Brno (Fig. 1) on a large clearing reforested in the spring of 2010 by two-year, container-grown seedlings of Norway spruce (*Picea abies*), 3,000 plants per hectare, and bare planting seedlings of European beech (*Fagus sylvatica*), 10,000 plants per hectare. The area is located in Training Forest Enterprise Masaryk Forest Křtiny, Habrůvka Forest District (49° 32.629' E; 16° 71.709' E).

It was a homogeneous area in terms of both habitat (an acidic site, 4 K 3 sets of forest types; the oligotrophic cambisol as the soil type, northern exposure, identical lighting conditions throughout the area) and the type and ground cover of weeds. Species and ground cover of weeds were recorded using phytosociological relevés; the repetition of the relevés was carried out in the late summer of the second year of measurements. Eudominant weed species (over 10%) occurring on clear cuts after treatment involved *Rubus idaeus* (average proportion of 37%), present on 30 plots out of the total of 35, *Calamagrostis epigeios* (16.5 %), which occurred on 22 plots, and *Senecio sylvaticus* which had eudominant representation on 2 plots with spruce planting. In addition, 21 more species of weeds were recorded, existing mainly in subrecedent representation (1% or below).

The area was split into plots with various treatments against weeds: total mowing with a brush cutter, mowing with a brush cutter in the strips with plants, brush cutter mowing around trees (spot treatment), total herbicide application, herbicide application in the strips with plants, herbicide application around trees (spot treatment). Plot 7 was a control plot with no action against weeds. A total of 3 series of plots were monitored areas for spruce, i.e. 21 plots, and 2 series of areas were surveyed for beech, i.e. 14 plots.

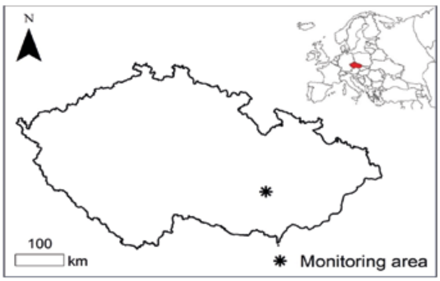

Fig. 1. Locations of experimental areas

Chemical treatment made use of Roundup Classic, at a concentration of 3%. The reason for this choice was imitation of concentration of application across the majority of forestry applications in the Czech Republic. Each of the plots contained permanent, marked squares of 20 × 20 m (400 sq m) for autumn and spring surveys of browse and measurement of height - after the end of the growing season in the autumn, and after winter browse in the spring. Height and thickness of the root neck of the key woody species were determined after the end of the growing season in the autumn of 2013, after winter browse in the spring of 2014, and, eventually, in the autumn of 2014 so that one could evaluate the difference in growth between individual years. Mortality was checked within the same dates (the rate of dead individuals).

Browse by game was measured for all woody species within a permanent square with height from 10 cm to 150 cm in the second half of April 2014 according to the methodology of ČERMÁK & MRKVA (2003). The presence/absence of the current damage was evaluated, with respect to the preceding winter / growing season; damage to the terminal and to the lateral shoots was classified separately.

2.2 Data analyses

Analysis of weed communities was tested by Permutation Multivariate Analysis of Variance (PERMANOVA) using the Bray-Curtis distance. Bray–Curtis distance is a normalization method that is commonly used in botany, ecology and environmental sciences. Bray–Curtis indices take values from zero to one. In a similarity index, a value of 1 means that the two communities you are comparing share all their species, while a value of 0 means they share none. In a dissimilarity index the interpretation is the opposite: 1 means that the communities are totally different. A multi-dimensional method similar to the Fisher F test, PERMANOVA compares the intra-group variability against that between groups (ANDERSON, 2001); 100 permutations were used per test. The results were shown using Non-metric Multidimensional Scaling (NMDS), a non-parametric two-dimensional graph, through the meta MDS function and the Bray-Curtis distance (OKSANEN et al. 2012). NMDS ordination can be used to plot samples using a community dissimilarity matrix based on species composition. Communities that have very similar species composition will appear as points near each other whereas communities that have very different species compositions will be further away from each other on the plot. Points can be color coded by categorical factors so you can see the grouping of samples based on categorical environmental factors. In order to determine whether samples are significantly different by one of the categorical environmental factors you can perform a permutational ANOVA (PERMANOVA) on your presence/absence matrix. NMDS ordination was conducted using the function 'metaMDS' (OKSANEN et al. 2012). The effect of each treatment on major forestry-economic parameters (growth, damage) was analysed using a linear model with a log-normal distribution (LM). Mortality in the investigated species of trees in relation to the treatment being done against weeds was assessed using a generalised linear model with a binomial distribution (GLM) with a logit link. Statistically significant analysis (H_0 rejected) was supplemented by multiple comparisons between the spot treatments carried out using Tukey's range test with Bonferroni correction. The relationship between damage, height, thickness, weed ground cover and the type of treatment was analysed using analysis of covariance (ANCOVA) with log transformed values [log (N + 1)]. Tree height was assessed as a dependent variable; the basal diameter and weed ground cover were covariates and treatment was used as categorical variable. Data analysis was carried out using the R program (THE R CORE TEAM 2015) with a level of significance of $p < 0.05$.

3. Results

3.1 The influence of the type of treatment against weeds on the growth of woody species

Both the type and the intensity of the treatment carried out were presented as a factor influencing the growth of woody plants. *Picea abies* reached the greatest height and thicknesses in plots with total/strip treatment, while the smallest increase was recorded in plots with spot mowing and control plots, where appropriate (Fig. 2 A, B). Comparing the height of trees in plots with variant treatments and control strip treatments resulted in statistically significant positive difference for all the three variants of herbicide spraying and a significant negative difference for spot mowing. For thickness, only positive significant differences were found against the control plot, which occurred for the all variants of treatment except spot mowing.

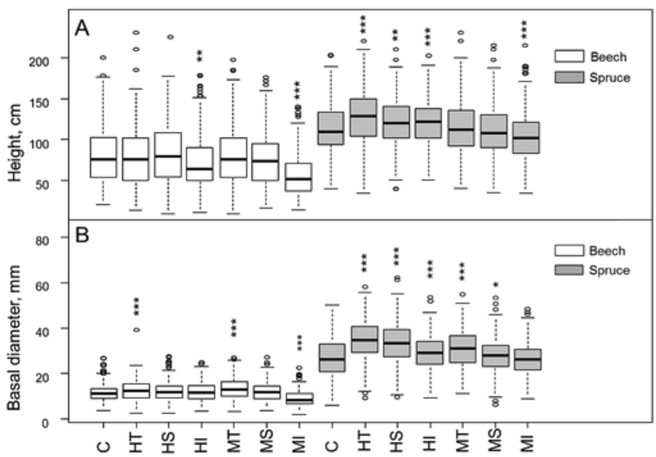

*Fig. 2. Height (A) and thickness of woody plants (B) in relation to the type of treatment (October 2014) Treatment: C = control plot, HT = herbicide total treatment, HS = herbicide strip treatment, HI = herbicide spot treatment of individual trees, MT = mowing total treatment, MS = mowing strip treatment, MI = mowing spot treatment of individual trees. Significance levels: *, p < 0.05; **, p < 0.01; ***, p < 0.001*

For *Fagus sylvatica* the difference between the treated plots and the control plot was less conclusive; the smallest increase was measured for beeches between areas treated individually by mowing around the seedlings. Comparing the height of woody species in spot treatment variants with the control plot were found statistically significant negative differences for both the treatment types, i.e. for both the spot herbicide treatment and spot mowing. For thickness, positive significant differences were found against the control for both the total operations (both herbicide and mowing); and a negative significant difference was found for spot mowing.

When comparing herbicide application and mowing, both of the woody species grew bigger on plots treated by spraying than on the areas treated by mowing. Differences were found even when comparing the total treatment against the spot treatments. For mowing, significant differences were found between these two levels of treatment intensity at a high level of statistical significance for both of the woody plants as well as the other parameters monitored - in the case of total treatment, the woody species height and root neck thickness were greater. For herbicide spraying, only a significantly greater thickness of root collar was found on spruce in the plots receiving the total treatment (Tab. 1).

Tab. 1. Influence of selected weed control technologies on growth of woody species

treatment	Fagus sylvatica				Picea abies			
	height		basal diameter		height		basal diameter	
	t-value	pr(>|t|)	t-value	pr(>|t|)	t-value	pr(>|t|)	t-value	pr(>|t|)
control - all treatment	3.314	**< 0.001**	-0.489	**< 0.001**	-1.398	**< 0.001**	-6.499	**< 0.001**
herbicide - mowing	5.179	**< 0.001**	5.001	**< 0.001**	6.911	**< 0.001**	7.071	**< 0.001**
herbicide total - herbicide spot	0.434	0.664	0.7782	0.3779	3.4874	0.06228	12.029	**< 0.05**
mowing total - mowing spot	29.348	**< 0.001**	92.254	**< 0.001**	10.899	**< 0.001**	17.781	**< 0.001**

3.2 Weed ground cover and species composition

When changing the treatment intensity, the weed ground cover also changed as expected. The average weed ground cover ranged from 44% on plots with total herbicide treatment to 87 % for control plots with no treatment after the implementation of the treatment. On plots that received strip treatment, the average weed ground cover was 50%; on plots treated individually around the seedlings the average ground cover was 62%. Prior to the treatment, weed ground cover matched the values indicated on the control plots - an average of 87%.

The technology of the treatment significantly influenced the weed species composition (Fig. 3 A, B). For *Picea abies* plantations, there was a predominance of dicotyledonous plants growing after total spraying, proliferating mostly by seeds (mainly *Senecio sylvaticus*, *Impatients parviflora*, *Erechtites hieraciifolius* and *Epilobium angustifolium*). *Senecio sylvaticus* occurred in a total of 16 plots, the representation was 0.9%; *Epilobium angustifolium* in 19 plots, the representation was 0.2%; *Impatiens parviflora* in 11 plots, the representation was 0.1%; and *Erechtites hieraciifolius* occurred in 4 plots, the representation was 0.05 %. At a lower treatment intensity, i.e. when spraying in strips, the relative representation of *Rubus idaeus* and *Calamagrostis epigeios* was found to be higher, but species present after the total spraying still occurred as well, although the representation was minor. These two variants of treatment produced a separate group in the NMDS analysis results (Fig. 3). Conversely, the variants of herbicide around seedlings, all the three variants of mowing and the control plot form a cluster in the NMDS results, with differing levels of mutual overlapping (Fig. 3 A). Semi-shrubs and grasses clearly prevailed in the plots after the treatment. *Rubus idaeus* and *Calamagrostis epigeios* were reaching the largest abundance, and species such as *Luzula nemorosa* and *Juncus conglomeratus* occurred increasingly. Dicotyledonous herbs were missing almost entirely.

For *Fagus sylvatica* the representation of individual weed species was slightly different, although the NMDS results displayed individual variants similarly as with spruce (Fig. 3B). The species mostly represented after total spraying included *Rubus idaeus* followed by *Calamagrostis epigeios* and *Senecio sylvaticus*. Species such as *Cirsium arvense*, *Petasites albus* and *Fragaria vesca* also appeared. *Rubus idaeus* and *Calamagrostis epigeios* clearly dominated after strip spraying; dicotyledonous herbs disappeared. For spraying around the seedlings, the species composition was similar to the plots with spruce in all the mowing treatments and the control plot – *Rubus idaeus*, *Calamagrostis epigeios*, *Luzula nemorosa*, and *Juncus conglomeratus*.

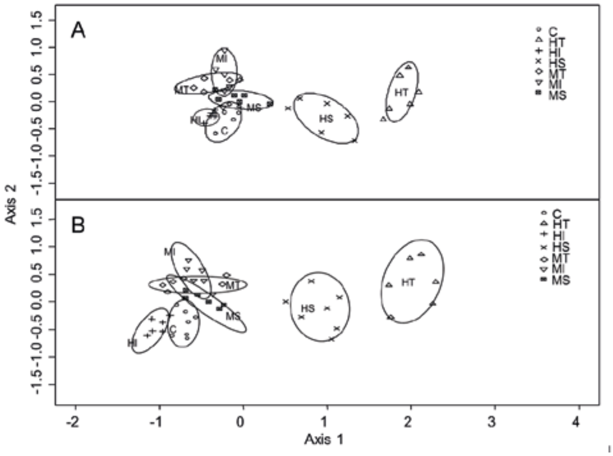

Fig. 3: Weed community Picea abies (A), Fagus silvatica (B) Non-metric multidimensional scaling (NMDS) Treatment: C = control plot, HT = herbicide total treatment, HS = herbicide strip treatment, HI = herbicide spot treatment of individual trees, MT = mowing total treatment, MS = mowing strip treatment, MI = mowing spot treatment of individual trees.

3.3 Browsing damage

Both species of trees suffered browsing damage almost equally; 4.4% of *Fagus sylvatica* individuals and 4.2% of *Picea abies* individuals were damaged. For *Fagus sylvatica* the damage was significantly different (higher) from the control only on the plot that received total treatment with herbicide (Fig. 4). For *Picea abies* the situation was quite different. Trees on plots with total and strip treatment suffered significantly less damage than those on the control plot.

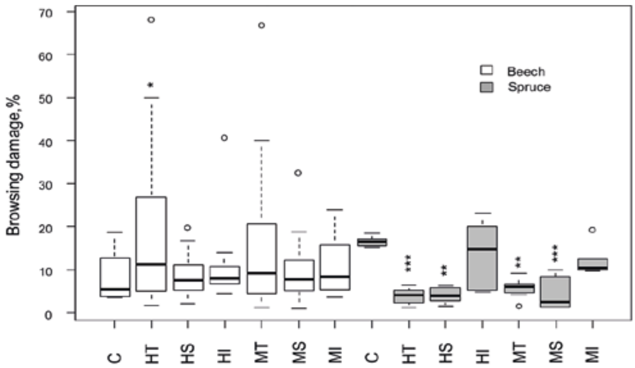

Fig. 4: Browsing damage
*Treatment: C = control plot, HT = herbicide total treatment, HS = herbicide strip treatment, HI = herbicide spot treatment of individual trees, MT = mowing total treatment, MS = mowing strip treatment, MI = mowing spot treatment of individual trees. Significance levels: *, p < 0.05; **, p < 0.01; ***, p < 0.001.*

Tab. 2. ANCOVA relationship between damage, height, thickness, weed ground cover and type of treatment

Damage	Beech		Spruce	
	F-value	pr(>F)	F-value	pr(>F)
Height	15.907	**< 0.001**	16.4336	**< 0.001**
Basal diameter	0.2453	0.62145	0.0948	0.76096
Weed ground cover	0.0637	0.801272	11.6835	**< 0.01**
Treatment	2.1141	0.057932	1.5585	0.197629

When comparing the effect of height, thickness, weed ground cover and treatment, the height of woody species had a significant effect on the abundance of browsing damage in particular - this was significant in both of the species (Tab. 2). For *Fagus sylvatica* the height of seedlings damaged most often was 40 cm to 95 cm; for *Picea abies* the damage concentrated to affect trees from 60 cm to 100 cm high. Woody species with a height lower or higher than the above were damaged only exceptionally. For *Picea abies* a significant relationship was also found between the weed ground cover and the percentage of trees damaged by game – as weed ground cover was reduced, the damage from the game increased.

3.4 Mortality

The mortality was higher for *Fagus sylvatica* compared with *Picea abies*, with numbers of seedlings lost over two years being 157 and 70, respectively. The type of treatment affected mortality in both woody species (LM, df = 8.122, $p < 0.001$). Beeches had the highest mortality on plots treated with herbicide (over 100 individuals). The lowest mortality was found for control plots (only 8 individuals). Lost specimens of spruce were mostly recorded for plots where weeds were eliminated in the immediate vicinity of the seedling (HT, HI, MT). Somewhat higher mortality was recorded on control plots (Fig. 5).

A statistically demonstrable deviation was mostly found for *Fagus sylvatica* only when comparing the control plot with each of the treatments. For *Picea abies*, there were marginal differences when comparing the control plot with each of the treatments, except spraying in strips. Here, the mortality was only 4 specimens compared with the control, where 11 were lost.

When comparing the technology of spraying against mowing statistically significant difference was found only for *Fagus sylvatica* (LM, df = 6.255, $p < 0.001$). Mortality for treatment by spraying was far higher than for mowing (101 individuals when spraying, 48 plants for mowing). For *Picea abies* the difference between spraying and mowing was not significant (34 plants when spraying, 25 trees when mowing). The effect of tree browsing on mortality was not demonstrated.

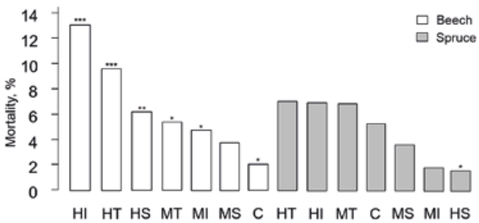

Fig. 5. Comparing mortality for different types of treatment
*Treatment: C = control plot, HT = herbicide total treatment, HS = herbicide strip treatment, HI = herbicide spot treatment of individual trees, MT = mowing total treatment, MS = mowing strip treatment, MI = mowing spot treatment of individual trees. Significance levels: *, p < 0.05; **, p < 0.01; ***, p < 0.001.*

When comparing the effect of the treatments on *Picea abies* growing bigger in general, the best result occurred for total herbicide treatment. Trees on such plots exhibited the highest thick and height growth and average damage by game while showing the biggest rate of mortality. For *Picea abies*, the worst growth rate was found on control plots – the smallest growth, average mortality rate, and the highest degree of damage by game were observed on the plots.

For *Fagus sylvatica* the results are not as clear as with *Picea abies*. Beeches reached the greatest height on plots with strip spraying; the biggest thickness was found for total mowing by brush cutter. On the other hand, these very areas with reduced weed showed the greatest extent of damage by game. Mortalities were mostly recorded for the spot spraying treatment. Beeches prospered the most on plots without weed control; while these showed average height growth, there was no damage by game and even no significant mortality.

Based on this survey, particularly strip treatment can be recommended in terms of forestry practice in that it appears to be an acceptable/safe trade-off from the perspective of risk, time and material expense as well as in terms of the growth rate.

Tab. 3: Total summary of the parameters compared to control plot for individual woody species and variants of treatment in the form: the lower than control plot – the higher than control plot. Treatment: C = control plot, HT = herbicide total treatment, HS = herbicide strip treatment, HI = herbicide spot treatment of individual trees, MT = mowing total treatment, MS = mowing strip treatment, MI = mowing spot treatment of individual trees. The bold words define significant difference on significance level p < 0.05.

	Picea abies				Fagus sylvatica			
treatment	height	basal diameter	browsing damage	mortality	height	basal diameter	browsing damage	motrality
HT	**higher**	**higher**	**lower**	higher	lower	**higher**	**higher**	**higher**
HS	**higher**	**higher**	**lower**	**lower**	higher	higher	higher	**higher**
HI	**higher**	**higher**	lower	higher	**lower**	higher	higher	**higher**
MT	higher	**higher**	**lower**	higher	higher	**higher**	higher	**higher**
MS	lower	**higher**	**lower**	lower	lower	higher	higher	higher
MI	**lower**	lower	lower	lower	**lower**	**lower**	higher	**higher**

4. Discussion

4.1 Growth and mortality in various types of treatment

The results of our experiment confirm that competition for light leads to a significant limitation of the growth of woody plants, under certain circumstances. For *Picea abies*, more than 50% coverage of weeds significantly retarded the growth of trees. In areas where there were less weeds, spruce normally reached about 30 cm greater height and 10 mm greater thickness than in plots where weeds covered more than 50% of the area. Similar differences were established by NILSSON et al. (1996), where they recorded almost 20 cm more height for spruce on areas treated with total spraying compared with the control. Similar research by JYLHÄ & HYTÖNEN (2008) carried out on spruce plantations found that spruce trees were growing better in direct proportion with increasing intensity of weed control; other significant negative influences on seedlings were only exhibited when the vegetation cover exceeded 70% of the area. In an earlier survey of *Pinus sylvestris*, JYLHÄ & HYTÖNEN (2006) demonstrated a statistically significant correlation between the density of ground vegetation and the parameters monitored: trunk diameter, height, trunk volume, and pine mortality. Mortality, height and trunk volume of pine significantly correlated with increased ground cover of weeds. The trend was confirmed in the present survey when comparing the intensity of total treatment against spot treatment. Under the high-intensity treatment, weeds covered 20% less than areas with spot treatment and seedlings grew faster.

When spraying herbicide our survey found a significantly greater thickness of the root collar of *Picea abies* in plots that experienced the total weed control treatment (Fig. 2B). The expected result that conifers responded to reduced weed competition through increased thickness was evidenced by a number of other studies, e.g. for *Picea abies* (JYLHÄ & HYTÖNEN 2006) - increased weeds caused trunk volume per hectare to reduce within growing season 2 for *Pinus strobus* and *Picea glauca* (BRAND & JANAS 1988) or even for *Picea mariana* (MORRIS et al. 1990) and *Pinus resinosa* (ELLIOTT & WHITE, 1993).

Picea abies has a surface root system and the young seedlings have the greatest distribution of the roots above a soil depth of 10 cm (NILSSON et al. 1996) where the most of weed roots also occurs. Consequently, spruce trees respond to weed competition and other stressors with reduced vigour usually far more than other woody plants (JOBIDON et al. 1998, SANDS & NAMBIAR 1984). In this case, the increased growth following the total or strip treatment was most likely caused by minimising weed competition in the immediate vicinity of the root systems of the spruce trees. This phenomenon, however, may not be mandatory; for example, in plantations of *Picea engelmanii* from British Columbia, weed removal close to the seedlings did not influence their growth in any manner (COATES et al. 1991).

Seedlings of *Picea abies* in plots with total treatment, however, exhibited the highest mortality rate, with no difference between the treatment technologies used (Fig. 5). The probable cause was, once again, the changed availability of water - while weed removal led to reduced competition benefitting well-rooted spruce trees, it also caused excessive drying of the upper layers of the soil. The damage done to the seedlings by the weed control operation alone had probably some influence on mortality as well.

The relatively high mortality of *Picea abies* on control plots was probably chiefly caused by weed competition. A similar result was attained by JYLHÄ & HYTÖNEN (2008), when the mortality they recorded on the control plot was up to 40% higher than in the weed control treatment. In this case, spruce trees were dying out to the least extent on medium-intensity treatment (HS, MS, MI), where some weed presence provided partial shading of the area, thus lessening evaporation (BENAYAS et al. 2005).

Results for *Fagus sylvatica* are ambiguous in general - the growth was relatively balanced on plots with various technologies and intensity of weed control treatment. This may be due to the fact that beeches can withstand drought better and are not so responsive to temperature fluctuations as other woody plants rooted in the top soil layers (BACKES & LEUSCHNER 2000, GARCÍ-PLAZOLA & BECERRIL 2000). Beech roots grow deeper than those of weeds, so they are not as influenced by weeds as other competitors (BURCH et al. 1997). Since young oak trees are quite tolerant of shading, they can do well under competition for light, too (ELLENBERG 1988). The positive effect of weeds on height observed another literature (e.g. WILLLOUGHBY et al. 2004, ŠPULÁK 2008) was not encountered on the study plots.

The type of treatment also had an influence on mortality of beech. The highest rate of mortality was observed on plots treated with herbicide, while the lowest rate was achieved on control plots (Fig. 5), which is different from spruce, which showed more than doubled mortality on control plots. For spraying technology the rate of mortality was significantly higher than for mowing (Fig. 5), which can be chiefly attributed to the weed control operation alone. Spraying with glyphosate is a non-selective treatment and can damage the significant proportion of the woody plant when hit (JYLHÄ & HYTÖNEN 2006).

4.2 Comparing herbicide treatment and mowing treatment

When comparing herbicide application and mowing, *Picea abies* grew better on plots treated by spraying. This fact can be related to the species composition of the weeds. Spraying destroys the entire plant including the root system. Mowing may result in weed propagation or develop the root system of the weeds; the roots may remain operational and are still able to compete for water. After herbicide application, surfaces thus prepared are often colonised by dicotyledonous herbs which have a different structure of the root system than e.g. grasses, such as *Calamagrostis epigeios*. The roots of dicotyledons compete with the seedling to a lesser extent enabling it to grow better. A similar phenomenon was seen previously by SIIPILETHO (2001) or JYLHÄ & HYTÖNEN (2008), where intense treatment by herbicide made grasses disappear, replaced by species such as e.g. *Ranunculus repens*.

Fagus sylvatica also grew better on herbicide-treated areas than on mowed areas, although differences in height were very small (Fig. 2). This conclusion has been demonstrated by other studies repeatedly as well; BENAYAS et al. (2005) even found that oak seedlings grew better on control plots than on mowed plots.

4.3 Browsing damage across treatments

Both woody species were damaged by browsing almost equally, about 4% on average, which is a relatively small extent and is not assumed to affect the growth of cultures. For *Fagus sylvatica* the damage was significantly higher than on the control plot only in the area treated with herbicide. On the treated plots, seedlings were far more noticeable for game than on areas with the presence of weed. In winter, when browsing pressure is highest, game can also move better when weeds are not present, and there are almost no other available food sources. The influence of high seedling visibility had been confirmed in previous research by ČERMÁK et al. (2011) in spruce plantations at three sites in the Czech Republic. In all the cases they found significant damage by browsing on plots treated with herbicide regardless of the intensity of the action in comparison with the control plot.

For *Picea abies* the situation was different. Young trees on plots with total and strip treatment were significantly less damaged than those on the control plot, which is not usual. ANOVA identified a significant effect of height on the frequency of browsing damage for both woody species. On control plots spruce trees had the smallest height gain differential compared with other plots, which was probably the reason for them attracting browsers, especially for being more visible than broadleaves in weeds.

Minor browsing may not affect the woody species survival and growth; indeed, it may have a positive effect on the growth; e.g. O'DEA et al. (2000) found that minor browsing damage to woody species on plots with reduced weeds made the plants grow faster out of reach of the game and recover better after damage.

5. Conclusions

Our results show that a higher presence of weeds in *Picea abies* caused seedlings to grow slower and increase their mortality rate. No other considerable damage by browsing occurred on plots with reduced weeds. *Picea abies* was the fastest to grow on plots with total chemical treatment, where, removal of a large proportion of the weeds caused high water evaporation, which also caused higher mortality of seedlings. The medium-intensity treatment appeared to be the best option for spruce under these conditions of habitat and climate.

For *Fagus sylvatica* the competition between seedlings and weeds did not have a significant, observable influence on the capability of growing out or growth of the mortality. While total herbicide treatment led to a slightly better capability of beech seedlings to grow, it occurred at the expense of mortality, which was considerably higher in this case. Total treatment also leads to an increase in the visibility of seedlings, which led to increased damage by browsers. Therefore, the medium-intensity treatment could also be recommended for beech.

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