Growth response of *Alnus viridis* to application of crushed limestone and amphibolite and forestry potential of the species in harsh acidic mountain sites

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ABSTRACT: An experiment with seedlings of *Alnus viridis* was established on a clear-felled tract situated on a summit tableland of the Jizerské hory Mts. (central Europe, Czech Republic) at an altitude of 980 m a.s.l. The aims of the experiment were (i) to evaluate the response of *A. viridis* to the application of a basic mixture containing crushed limestone and amphibolite and (ii) to assess the growth potential of the species in a poor acidic site under climatically harsh conditions. *Alnus viridis* showed a good growth performance and survival rate, its initial response to fertilization was positive. The height growth and expansion of crowns were slightly but significantly stimulated by the treatment, the survival rate was also increased, though not significantly. The amendment application temporarily increased the foliar Ca and Mg concentrations. The content of foliar P, of the most deficient macroelement, was not improved by the treatment. However, the positive effect of fertilization was short-lasting and unconvincing from the aspect of practical use. In the second half of the reference period the control started to gain on the fertilized variant and as for mean height and crown diameter, both variants got almost equalized eight growing seasons after the treatment.

Keywords: *Alnus alnobetula*; amelioration; *Duschekia alnobetula*; initial fertilizing; Jizerské hory Mts.

The taxonomy of *Alnus* has been rather complicated, resulting in several classification systems. In the recent cladistic approach, three major clades are recognised in *Alnus* that can be designated as subgenera *Alnobetula*, *Clethropsis*, and *Alnus* (Chen, Li 2004). The "*Alnus viridis* complex" has been defined within the *Alnobetula* subgenus. The "*Alnus viridis* complex" consists of *Alnus crispa, Alnus fruticosa,* and *Alnus sinuata* of North America, *Alnus maximowiczii* and *Alnus mandshurica* of eastern Asia, and *Alnus viridis* of Europe (Chen, Li 2004). In more concrete terms, Chen and Li (2004) reported the occurrence of *Alnus viridis* in southern Europe and paid no heed to the populations in Central Europe. However, for further reference we assume that the *Alnus viridis*, as a species distinguished by Chen and Li (2004), encompasses the "green alder" populations also in Central Europe.

Populations belonging to the "*Alnus viridis* complex" have often been recognized as either species or subspecies (e.g. *Alnus crispa* vs. *Alnus viridis* ssp. *cripsa*). Moreover, several synonymous Latin

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names have been used for European populations of green alder: *Alnus alnobetula* (Ehrh.) C. Koch, *Duschekia alnobetula* Ehrh. Pouzar or *Alnus viridis* Chaix DC. To avoid problems with the scientific nomenclature, we have decided to use the English "green alder" for any of the representatives of the "*Alnus viridis* complex" or to specify the particular species in question with Latin names used by Chen and Li (2004) if need be.

In Europe green alder occurs mainly in the Alps (Anthelme et al. 2001; Kamruzzahan 2003; Wiedmer, Senn-Irlet 2006) and Carpathians Dinaric chains (Kamruzzahan 2003; Wiedmer, Senn-Irlet 2006). In the Czech Republic green alder grows naturally in several localities in southern Bohemia and southwestern Moravia, elsewhere it was spread artificially by forestry cultivation (Kubát et al. 2002; Úradníček et al. 2009).

In the Western Alps, green alder stands are widely spread at an altitude of 1,000–2,000 m a.s.l., mostly on moist, north-exposed slopes on the siliceous bedrock (Wettstein in Wiedmer, Senn-Irlet 2006). The shrub is often cultivated as a soil protecting species, because its stands are able to prevent soil erosion and avalanches (Richard in Anthelme et al. 2001). Green alder seems to be a potentially suitable species for preparatory stands in climatically harsh degraded sites. Nonetheless, potential risks and legislative obstacles are inherent in its forestry cultivation in the Czech Republic. Moreover, the opinions are rather discrepant concerning the requirements of *A. viridis* for soil chemistry (e.g. Ellenberg 1988; Úradníček et al. 2009).

The aims of the present paper were (i) to evaluate the response of *A. viridis* to the application of a mixture containing crushed limestone and amphibolite and (ii) to assess the growth potential of *A. viridis* in a poor acidic site under climatically harsh conditions (with respect to the benefits and hazards of forestry cultivation of *Alnus viridis* in the Czech Republic).

MATERIAL AND METHODS

The experimental plantation of green alder was established as a part of the Jizerka Field Experiment (Balcar, Podrázský 1994) in the climatically most exposed section of the Jizerka research plot (FGMRI) which is situated on a clear-felled tract in the summit part of the Central Ridge in the Jizerské hory Mts. (latitude 50°49'34"N, longitude 15°21'19"E, Northern Bohemia). The mean annual air temperature (1996–2007) at the site is 5.1°C and the mean annual precipitation (1994–2007) is 1,093 mm (Balcar, Kacálek 2008). The bedrock was determined as biotitic granite, the soil as peat Podzol. The average air SO_2, NO_2, O_3 concentrations in the post-air-pollution period are 4 $\mu g \cdot m^{-3}$ (2005–2008), 5 $\mu g \cdot m^{-3}$ (2006–2008) and 102 $\mu g \cdot m^{-3}$ (2003–2008), respectively; see Balcar, Kacálek (2008).

The experimental plantation was established in May 2000. Two-years-old container-grown seedlings of *A. viridis* were planted in two variants. Apart from the control, a fertilized variant was established. Each variant consisted of 100 seedlings distributed at the spacing of 1 × 2 m.

In the fertilized variant, a mixture of crushed dolomitic limestone and amphibolite was applied 2 years after planting in May 2002. Each rock component comprised 50% by weight of the mixture. The mixture was applied as a base dressing around alder seedlings in circles of approximately 0.5 m in diameter. The dose was 1 kg per tree.

The crushed dolomitic limestone (56.7% of $CaCO_3$ and 39.4% of $MgCO_3$) contained 93.5% of particles smaller than 1 mm in diameter and the pulverized amphibolite (11.1% of CaO, 7.3% of MgO, 0.18% of P_2O_5, 0.23% of K_2O) contained 45.5% of particles smaller than 0.06 mm, 46.6% of particles between 0.06 and 0.1 mm, 6.3% of particles between 0.1 and 0.6 mm and 1.6% of particles larger than 0.6 mm in diameter.

Tree heights were measured to the nearest 1 cm, crown diameters to the nearest 5 cm. The crown diameters were measured twice in two perpendicular directions. The height increment is considered as a difference between two subsequent dates of measurement. Thus it can also show negative values, which can be explained by the fact that green alder shrubs are often sprawled by snow during winter and their crown diameters thus rise to some extent at the expense of their height, because the height of shrubs is depressed by force of snow. Assessment of survival and measurements of heights and crowns were carried out annually in autumn except for 2000 and 2002, when these characteristics were evaluated both in spring and autumn.

The nutrition analyses are expressed in percentages of macroelements (N, P, K, Ca, Mg, S) in dry matter of assimilatory tissues. A composite sample of leaves from each variant was taken in the period from mid-August to the beginning of September, after the aboveground parts of trees had finished their active growth. The samples were analyzed using the procedures described by Zbíral (1994).

The mortality rates were assessed by means of a binomial test described e.g. by Anděl (1998). The test was executed by S-Plus 6.1 software.

Height increment, stem-base diameter and crown diameter were statistically analysed using the Mann-Whitney *U*-tests. For the statistical procedure STATISTICA 8.0 (StatSoft Inc.) software was used, the applied method was described e.g. by Hill, Lewicki (2006).

Trends of the nutrition of plantations were evaluated using the linear-regression lines smoothing the macroelement concentrations recorded within a variant in the years of sampling. For the macroelements in particular variants, the existence of a significant divergence of the time axis and regression line representing the development in a macroelement concentration was examined. For each macroelement, a mutual parallelism of regression lines representing the compared variants was also tested. The methods are described by Anděl (1998) and were executed by S-Plus 6.1 software. The confidence level of 95% was chosen in all statistical tests.

RESULTS

The amendment was able to influence the survival of plantations positively. Between the spring 2002, when the amendment was applied, and the autumn 2009 the total mortality rate in the fertilized variant rose by 3% only, while that registered in the control rose by 11.1% (Fig. 1). Nevertheless this difference is too small to be significant at a 0.05 level.

The fertilization influenced also the height growth of the plantation (Table 1; Fig. 2). Between 2002 and 2006 inclusive, the mean annual height increment registered in the fertilized variant was higher than in the control, although the difference was significant only in 2005. As for the mean plantation height, the effect of accelerated height growth in the fertilized variant found a more pronounced expression; the lead of the fertilized variant after the amendment application had successively grown and became significant ($P = 0.05$) in three consecutive years from 2004 to 2006. The lead of the fertilized variant in mean height reached 12% when culminated in 2005 (Fig. 2). Then, however, the difference between variants began to decrease and finally, at the end of the reference period in 2009, completely vanished.

The 01a/02s value expresses a decrease in height during the winter season caused by snow and rime pressing the shrubs against the ground. The research area is exposed to extreme climatic conditions and it can be expected that the decrease occurs almost annually. This reduction in height during winter is usually compensated by height increment during the subsequent vegetation period before the shrub stand starts to decelerate its height growth rate in later stages of its development.

The mean values of crown diameter (Table 2) reflected the fertilization stimulus most distinctly. The differences between the variants were significant ($P = 0.05$) in favour of the fertilized variant for five consecutive years between 2003 and 2007. The greatest difference in crown diameter was registered in 2005, when the fertilized variant exceeded the control by 23%. Since then, however, the lead of the fertilized variant became smaller. From 2008 onwards the differences in crown diameter became insignificant; although with 8% distance between the mean values (2009) they were still observable.

Tables 3 and 4 summarize macroelement concentrations in the assimilatory apparatus including

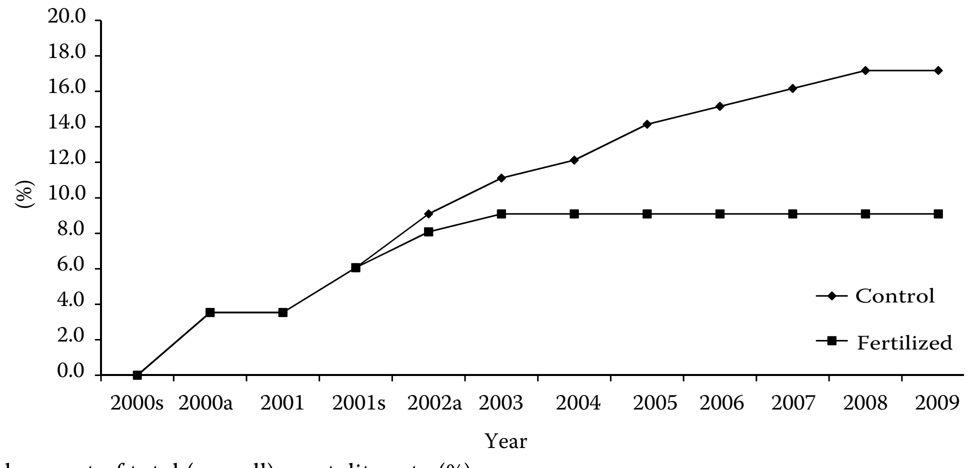

Fig. 1. Development of total (overall) mortality rate (%)

s – spring; a – autumn

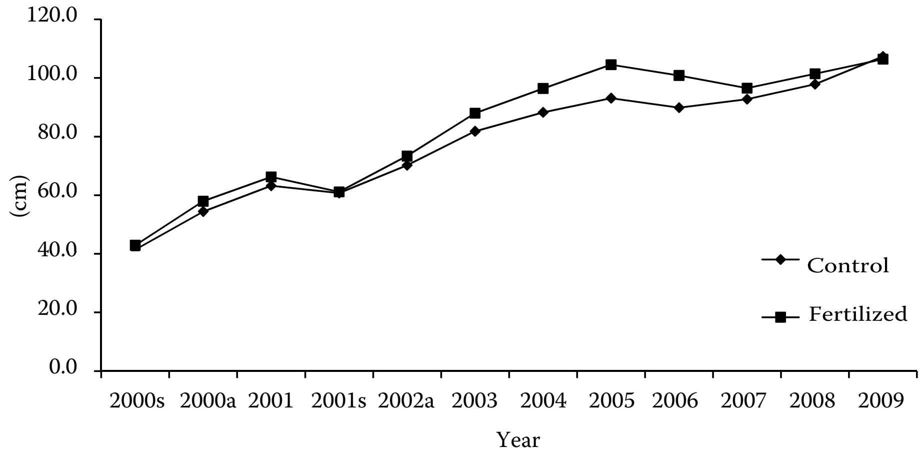

Fig. 1. Development of mean height

s – spring; a – autumn

their ratios. As an approximate range, the authors used the limits of nutritional status for *A. crispa* suggested by Prégent and Camiré (1985) and for speckled alder (*A. incana*) those proposed by Kopinga and Burg (1995).

With the exception of 2003, when the N concentration in dry mass of leaves in the control dropped below the value of 2.5%, N concentrations were in the range indicating normal or adequate N supply in both variants. The interannual fluctuation in N concentrations seems to play a more important role than the differences between variants.

By contrast, the P supply seems to be limited in both variants. In the course of the reference period (2002–2009) P concentrations were low and never reached the range of normal or adequate P status. Actually, in 2009, the P concentration in the fertilized variant declined below the limit of deficiency. This limit equals 0.12% of dry mass for *A. crispa*, and 0.11% for *A. incana*.

In the control and in fertilized variants, foliar K concentrations were gradually rising between 2003 and 2009. A significant upward trend was confirmed between 2002 and 2009 with *P*-values of 0.03 and 0.04, respectively. According to the criteria defined by Kopinga and Burg (1995), K concentrations gradually increased from low to normal level of the nutritional status. Nonetheless, according to the criteria suggested by Prégent and Camiré (1985) the concentrations were sufficient or adequate in both variants from the very beginning. The K supply to plants seems not to have been influenced by fertilization.

There was a margin in foliar Ca and Mg concentrations in favour of the fertilized variant that was apparently induced by the application of the amendment. This margin was nonetheless gradually vanishing and for both basic macroelements it completely disappeared prior to 2009 (vanishing of the fertilization effects). However, the authors consider the foliar Ca concentrations recorded between 2002 and 2009 as normal or optimal. It is so because also the foliar Mg concentrations of alders in both compared variants, despite a decreasing tendency after 2003, remained safely within the range of normal or optimal status (> 0.13% and > 0.16% of dry mass according to Prégent and Camiré (1985) and Kopinga and Burg (1995), respectively).

Foliar S concentrations show persisting consequences of an extreme S load in the past (Křeček, Hořická 2002; Hrkal et al. 2006). However, S concentrations markedly decreased between 2002 and 2009. In the control, an overall downward trend of foliar S concentration between 2002 and 2009 was proved to be significant

Table 1. Development of annual height increment values (2000–2009); the 01a/i02s column expresses a decrease in height during the winter period before the amendment application

Variant		Year (*P*-value)										
		2000 (0.023)	2001 (0.560)	2001s/2002a (0.275)	2002 (0.379)	2003 (0.123)	2004 (0.314)	2005 (0.017)	2006 (0.698)	2007 (0.000)	2008 (0.841)	2009 (0.043)
Control	$\bar{x}$ (cm)	13.0[a]	8.8[a]	–2.5[a]	9.5[a]	11.6[a]	6.5[a]	4.8[a]	–3.2[a]	2.9[b]	5.1[a]	9.5[b]
	SD (cm)	6.67	8.07	8.88	11.45	12.74	11.12	9.77	10.22	10.06	10.23	10.60
Fertilized	$\bar{x}$ (cm)	15.0[b]	8.3[a]	–5.1[a]	12.2[a]	14.6[a]	8.4[a]	8.1[b]	–3.6[a]	–4.3[a]	4.9[a]	5.0[a]
	SD (cm)	7.66	8.24	11.61	13.09	11.83	10.08	12.89	10.77	13.90	9.89	9.87

SD – standard deviation, $\bar{x}$ – mean, values in the same column followed by the same letter are not significantly different

Table 2. Development of crown diameter values

Variant		Year (*P*-value)						
		2003 (0.040)	2004 (0.011)	2005 (0.001)	2006 (0.015)	2007 (0.031)	2008 (0.135)	2009 (0.180)
Control	$\bar{x}$ (cm)	61[a]	70[a]	77[a]	79[a]	85[a]	87[a]	99[a]
	SD (cm)	27.1	31.4	38.1	41.3	44.1	42.0	51.8
Fertilized	$\bar{x}$ (cm)	68[b]	83[b]	95[b]	94[b]	99[b]	96[a]	107[a]
	SD (cm)	26.0	33.0	38.7	43.1	41.9	39.9	46.7

$\bar{x}$ – mean, SD – standard deviation, values in the same column followed by the same letter are not significantly different

(*P* = 0.02). In the fertilized variant the linear downward trend of foliar S concentrations was insignificant (*P* = 0.06).

The values of the P:N ratio mostly indicate an insufficient proportion of P in relation to N. No significant upward or downward trend was observed in the P:N ratio in either variant.

The linear trend of the K:N ratio (2002–2009) was found to rise significantly in both variants (*P*-values in the control and fertilized variants equalled 0.01 and 0.03, respectively). Despite the gradually rising trend of the K:N ratio, the K proportion in relation to the content of N remained still somewhat low and indicated the relative K deficiency in relation to abundant N supply.

Significantly downward linear trends of the Mg:N ratio were detected showing the *P*-values of 0.02 and 0.01 in the control and fertilized variant, respectively. This indicates a decreasing level of abundance in the supply of Mg to plants. A significant mutual divergence (*P* = 0.02) of the linear trends in the Mg:N ratio was revealed as a result of a steeper decline in the Mg:N values in the fertilized variant as compared to the control, which indicates a vanishing effect of fertilization. The ratio of Mg to N, however, remained sufficient in both variants.

A significant upward linear trend (*P* = 0.03) in the K:Ca ratio was found in the fertilized variant. With increasing trends in K concentrations, the K:Ca ratios reached the adequate level in both variants.

As for the K:Mg ratio, a significant upward trend was revealed in the control (*P* = 0.03). In both variants the values of the K:Mg ratio remained adequate throughout the reference period.

DISCUSSION

Growth response of green alder to application of basic amendment

Alnus viridis is considered a calcifuge by some authors (Úradníček et al. 2009). However, Ellenberg (1988) suggested that it is indifferent as to

Table 3. Dry mass concentrations (in %) of macroelements in foliage of *A. viridis*

Year	Variant	N	P	K	Ca	Mg	S
2002	control	2.58	0.11	0.43	0.56	0.253	0.27
	fertilized	2.53	0.11	0.46	0.68	0.278	0.25
2003	control	2.45	0.14	0.46	0.51	0.320	0.25
	fertilized	2.62	0.13	0.44	0.72	0.380	0.24
2004	control	2.85	0.12	0.56	0.47	0.290	0.25
	fertilized	2.88	0.12	0.54	0.57	0.350	0.26
2007	control	2.84	0.12	0.59	0.46	0.280	0.18
	fertilized	2.68	0.12	0.54	0.53	0.290	0.23
2009	control	2.76	0.12	0.61	0.55	0.236	0.18
	fertilized	2.59	0.10	0.62	0.54	0.232	0.20

Table 4. Proportion values of nutrition elements to N (=100%) in dry mass of leaves (the 1st section of the table) and basic element ratios in dry mass of leaves (the 2nd section of the table)

Year	Variant	P	K	Ca	Mg	K/Ca	K/Mg
2002	control	4	17	10	10	0.8	1.7
	fertilized	4	18	11	10	0.7	1.7
2003	control	6	19	13	10	0.9	1.4
	fertilized	5	17	15	9	0.6	1.2
2004	control	4	20	10	9	1.2	1.9
	fertilized	4	19	12	9	0.9	1.5
2007	control	4	21	10	6	1.3	2.1
	fertilized	4	20	11	9	1.0	1.9
2009	control	4	22	9	7	1.1	2.6
	fertilized	4	24	9	8	1.1	2.7

the soil reaction; the water-holding capacity of soil seems to be a more important factor for green alder growth and competitiveness. Nerbas in Vogel and Gower (1998) likewise found that the presence of alder (*A. crispa*) clumps in jack pine forests in central Saskatchewan was indicative of soil textural changes that increased soil moisture.

The Ellenberg's opinion, disputing the assumed calcifugicity of *A. viridis*, is supported by our study showing the positive initial growth response of *A. viridis* to the application of a dolomitic limestone and amphibolite mixture and indicating (though not significantly) also a higher survival rate of the treated shrubs. Similarly, Scherer and Everett (1998) found out that *A. sinuata* cultivated on acidic copper mine tailings showed the best growth performance when treated with compost and lime.

In any case, green alder (at least *A. sinuata*) is highly tolerant to acidity, it is able to withstand pH as low as 2.6 (Scherer, Everett 1998).

As far as the height and crown diameters are concerned, the control variant was gaining on that fertilized in the second half of the reference period. It remains to be seen whether this trend will continue and the control will outperform the fertilized variant in the end or whether the growth rate of both variants will finally equalize. Nonetheless, it is most probable that the recent decrease in the growth rate of fertilized variant as compared to the control has nothing to do with calcifugicity because the immediate reaction of green alder to fertilization was positive.

In general, however, the effect of the basic amendment on growth is not persuasive. One of the possible explanations is that the amendment was not able to improve the P supply to alders. Based on our results and the analyses presented e.g. by Špulák (2009), phosphorus seems to be one of the most deficient macroelements in the area of interest. Moreover, the P requirements of N fixing plants are higher as compared to other species (Huss-Danell et al. 2002; Vitousek et al. 2002). The content and solubility in the applied mixture of crushed rocks were low. The influence of the limestone-containing amendment on dynamics and plant uptake of soil nitrogen might also play a role although the slightly basic nature of fertilizer is desirable because green alder might acidify the site.

From the viewpoint of a forest practitioner the application of the mixture of crushed basic rocks in order to promote the initial growth performance of green alder would not pay for itself (at least under our model conditions). An artificial slow-release fertilizer with a higher concentration of P might be advisable.

The dynamics of soil chemistry and the impact of the basic amendment on availability of nutrients in peaty soil might play a significant role although there was not found any significant (partial) correlation between the values of height growth and foliar concentrations of any of the analysed macroelements. Further investigations focusing on soil chemistry, soil macroelement interactions and their availability are needed.

Potential of green alder for forestry cultivation

Regarding the utilization of alders for forestry purposes, Van Miegroet and Johnson (2009) summarized the existing experiences by a comment: "The alder story: the good, the bad, and the complicated". For green alder in particular this comment seems highly perceptive.

Where the habitat is favourable, green alder is strongly competitive (Ellenberg 1988; Mallik et al. 1997) and is able to smother light-demanding species (Ellenberg 1988).

Anthelme et al. (2001) studied the expansion of *A. viridis* on abandoned pastures in the French Alps. Considering the vegetation diversity, they found out that the critical cover of dense alder shrubs in the area is 50%. Up to 50%, the alder occurrence is favourable for plant diversity (a mosaic of various light and microclimatic conditions). However, once the alder canopy covers 50% of the site and more, the effect of green alder stands becomes detrimental and reduces the species richness.

On the other hand, a question should be asked whether the green alder expansion in the Alps is not a natural stage of forest succession after the influence of livestock grazing has faded away. Of course, if the priority is to preserve the present state because of its valuable species diversity, it is understandable to take some actions against expanding alder. However, if the natural processes were the aim, green alder might be viewed as an important link preparing the sites for forest.

In North America, white spruce (*Picea glauca*) grows naturally beneath the canopy of shrubby alders for years before gradually overtopping it and becoming a dominant species. White spruce seems to tolerate the competition of alder (Van Cleve, Viereck in Wurtz 2000). The biggest obstacle of successful regeneration of white spruce is the competition of *Calamagrostis canescens* (Wurtz 2000; Cole et al. 2003).

Green alder belongs among the nitrogen-fixing species. The shrub shows a high potential to produce biomass as compared to other prostrate species growing under harsh environmental conditions. According to Rehder in Ellenberg (1988), *A. viridis* can deliver up to 250 kg·ha^{-1} of mineral N annually. An old-grown pure stand of *A. viridis* produces approximately 6.18 t of aboveground dry mass per 1 ha annually (alder exclusively; other components such as herb layer not included), of which 61.5% are allocated to leaves (Wiedmer, Senn-Irlet 2006). However, when the green alder stands are younger and/or not monospecific, the production and N accretion are not so great. Binkley (1982) and Binkley et al. (1984) studied the effects of *A. sinuata* on developing Douglas-fir (*Pseudotsuga menziesii*) stands and suggested that the annual net production of *Alnus* might be 4,900 kg of aboveground dry mass per ha and the estimated nitrogen accretion was approx. 30 kg·ha^{-1}·yr^{-1} for a period of initial 23 years of the stand existence. Mitchell, Ruess (2009) suggested that the N input by green alder might be even lower, nonetheless, they still considered green alder to be a significant N contributor.

According to Binkley et al. (1984), moderate N-fixation rates and shrubby shape make *A. sinnuata* closely relative to *A. viridis* – see Chen and Li (2004), an attractive species for a mixture with conifers in N-deficient sites.

Podrázský et al. (2005) evaluated the soil chemistry under an *A. viridis* plantation in the Jizerské hory Mts. (an alder experimental plantation established in 1992). They called attention to increased mineralization of surface organic matter, accelerated forest soil acidification due to nitrate leaching and higher losses of soil bases, which should be taken into account in an acidified mountain site. On the other hand, they concluded that green alder produced litter of favourable composition, recycled some nutrients more rapidly, and ensured nitrogen accretion for the forest ecosystem.

Our experimental plantation of *A. viridis* showed a good survival rate, relatively stable height growth and development of crowns. The shrubby shape and limited height of plantation (Fig. 3) indicate that the preparatory stand should not pose an obstacle to target species for a long time. The outcomes of our experiment as well as the studies by other authors (Lokvenc, Vacek 1993; Remeš, Podrázský 2002; Podrázský, Ulbrichová 2003) indicate that *A. viridis* might be a good preparatory shrub for cultivation in disturbed or degraded sites.

In the Czech Republic, the possibility of using green alder in mountain forests is often restricted by environmental legislation (many mountainous regions belong among specially protected areas), because the species is supposed to be autochthonous only in several areas in southern Bohemia and southwestern Moravia; elsewhere it was presumably spread artificially by forestry cultivation (Kubát et al. 2002; Úradníček et al. 2009).

Šach and Černohous (2009) academically disputed the approach of strictly classifying *A. viridis* as an allochthonous taxon in the major part of the Czech Republic, nonetheless *A. viridis* is legislatively being viewed in this way. If the species was spread artificially in (usually mountain) areas with

Fig. 3. Shrubs of *Alnus viridis* in 2007, i. e. seven growing seasons after planting on the acidified mountain site

an accented regime of nature preservation and conservation, it is considered as a potentially risky taxon (Dvořák 2004), though this artificial cultivation of green alder was mostly motivated by its protective function against natural hazards such as surface erosion, runoff or avalanches.

However, the above-mentioned facts do not mean that there is no need to glean the information about the potential of the species in the sphere of biological amelioration and regeneration of disturbed sites under harsh climatic conditions.

On the basis of literature review Šach and Černohous (2009) characterized green alder as a complex which comprises the species of non-mountainous sites in the boreal zone and mountainous sites in the temperate zone. Similarly, according to Anthelme et al. (2002) green alder is a substantial component of boreal forests, and the subalpine belt in European temperate mountain ranges at the upper treeline.

Under common environmental conditions, the forest dynamics (of natural forests) in central Europe is supposed to be driven mainly by small-scale gap-phase processes (Vacek et al. 2007). Nonetheless, some recent studies have suggested that large, infrequent disturbances (e.g. windstorm damage and subsequent insect outbreaks), as we know them from boreal forests, might also be a natural phenomenon in the coniferous mountain forests of central European region (Fischer et al. 2002; Svoboda, Pouska 2008).

Recently, large areas of spruce forests have been clear-felled in southern Bohemia in an effort to stop the bark beetle invading from the "zero management" areas in the Šumava Mts. (Bohemian Forest). Šumava is a region where *A. viridis* is accepted as a native species. Moreover, as far as grazing or browsing is concerned, green alder is not an attractive species to game (Ellenberg 1988; Lokvenc, Vacek 1993). This is an important moment, because the recently high hoofed game stocks (Vacek, Krejčí 2009) have not surely been in a close-to-nature state in Šumava and hoofed game have inevitably affected the colonisation of the dead forest by pioneer broadleaves. There is a "little" snag, as was mentioned above, green alder can be highly competitive and in the Alps it massively expands (Anthelme et al. 2002), though the existing experiences do not indicate any expansive tendency of *A. viridis* in the Krkonoše Mts. (Grundmann 2004) and the Jizerské hory Mts.

Some provocative questions: Could the autochthonous *A. viridis*, an early successional woody species in primary as well as secondary succession (Wurtz 2000; Anthelme et al. 2001), be used as a component of preparatory stands helping to replant the large clear-felled bark beetle "buffer belts" in the spruce mountain forests of the Šumava National Park? If it were cultivated and started to expand, how would this be viewed?

What is more risky:

(1) to use *A. viridis,* a functionally suitable, however potentially expansive, autochthonous species, which is relatively resistant to game browsing, for preparatory stands on the vast areas of clear-felled buffer belts (in the 2nd zones), or (2) to fully rely on spontaneous undistorted succession of new mountainous forests in sites disturbed with another autochthonous expansive (insect) species under the influence of existing unbearably high stocks of hoofed game (in the 1st zones)?

The authors do not know the correct answer without the reduction of hoofed game stocks.

CONCLUSIONS

Alnus viridis showed a good potential to survive and grow under harsh climatic conditions of an acidified waterlogged site situated on a flat summit of the mountain ridge. The initial growth response of *A. viridis* to the application of a mixture containing crushed dolomitic limestone and amphibolite was positive. The height growth and expansion of crowns were slightly but significantly stimulated by the amendment, the survival rate was also increased, though not significantly. But in the second half of the reference period the control started to gain on the fertilized variant and, as for mean height and crown diameter, both variants got almost equalized.

The amendment application temporarily increased foliar Ca and Mg concentrations. Nonetheless, the content of foliar P, of the most deficient macroelement, was not improved. Green alder does not seem to be a calcifuge as some authors assumed, nevertheless, the application of dolomitic limestone and amphibolite on peaty acidic soils has proved ineffective in our particular case. The application a slow-release basic amendment with a higher P concentration seems to be advisable.

In regions where green alder is autochthonous (and not viewed controversially), it might be used as a species applicable and suitable for preparatory stands because of its ability to fix nitrogen and produce a lot of foliar biomass. Its shrubby shape should allow the target species to overtop green alder in the end and become dominant.

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