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Reaction of Silver fir (*Abies alba* Mill.) plantation to fertilization

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ABSTRACT: Silver fir as a domestic species is an important tree in our forests. Unfortunately it has suffered from serious dieback in Central Europe in the last decades. Reintroduction of Silver fir is not an easy task as seedlings and saplings are sensitive to many environmental harmful factors and to game browsing damage especially in early stages after germination. The fertilization of Silver fir saplings could help shorten the sensitive period of the tree species. Silver fir research plots were founded in 1999 to observe an impact of different fertilizers on its height growth. Applications of conventional as well as modern fertilizers confirmed the positive influence on the height growth of the species. Apical dominance ratio was used to evaluate the growth status of saplings.

Keywords: Silver fir; site amelioration; species composition; reforestation; apical dominance

Silver fir was the most important coniferous species in our natural forests. Its original proportion was 18% while now it is less than 1% (Kupka 1999, 2000). There are different hypotheses explaining the reasons of this dramatic dieback of Silver fir in our forests. The most serious and promising hypothesis says that the acidification of our sites followed by nutrition leaching as a result of heavy acid deposition in the last decades in this country leads to an insufficient nutrition status and this may be the main reason for disappearing of Silver fir from our forests. This hypothesis could be supported by symptoms of revitalization of mature Silver fir in the last few years when air pollution was cut down in this country (Kantor, Paříк 1998; Lajtner 1999; Wolf 1998).

Silver fir has a deep root system with robust tap root. That is why Silver fir is one of the recommended species to increase the interim stability of our stands (so called stabilization and amelioration species) and we have to try to increase its proportion in our forests. The target proportion of Silver fir in our future forests should be about 4% of the total forested area.

However Silver fir is a climax species and its reintroduction to the forest is not an easy task. Silver fir seedlings and/or saplings could not be planted on bare soil after clear cutting as it is very vulnerable to extreme climatic conditions. Another drawback of this species is slow growth at the beginning of its existence which makes the plant and small tree assailable to weed competition and game browsing. Especially vegetation competition could be a serious problem for slow growing Silver fir (Canham et al. 1990). Environmental conditions are always critical even for a highly plastic species like Silver fir (Grassi, Bagnaresi 2001).

Therefore reforestation by Silver fir is an important but not easy assignment for our forestry. Fertilizations could be one of the promising ways to fulfil the job with a good level of achievement. Research plots with Silver fir were founded in 1999 at a training forest district of the Faculty near the town of Lounovice.

The two main goals of the research plots were:
– to analyze Silver fir reactions to site amelioration done by different fertilizers and their use,

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Table 1. Monthly precipitation in research area Lounovice

Month	IV	V	VI	VII	VIII	IX	X
Precipitation (mm)	45.1	77.5	79.1	84.7	80.2	51.4	53.2

Table 2. Fertilizers and their nutrient volume in percentage used in the trials

Fertilizer	N	P_2O_5	K_2O	MgO	Total
Cererit	7*	11	9	1	28
Silvamix MG**	10*	13	6.5	16	45.5

*The dose of each fertilizer was calculated in the way the nitrogen volume was equal
**Silvamix MG was applied in two forms (tablets and powder)

– to find out the basic rules and recommendations how Silver fir should be treated for reforestation with fertilization.

As the time span since the plot establishment is rather short, the results could be considered as preliminary and final recommendations may be drawn up after a longer period of observations.

METHODS AND PLOT DESCRIPTION

Research plots were founded in the forest nursery area near Lounovice at 420 m above sea level. It is a part of the Central-Bohemian pluton and thus the bedrock is biotite-porphyric granodiorite.

The soil is mesotrophic brown soil. According to Novak's classification it belongs to clay-sandy soil very rich in physical aspects but mostly acid, with a low nutrient supply. Exchange soil acidity lies between 4.3 and 5.98 with the average of 4.98 pH. It is slightly below the recommended pH soil reaction (5.0–5.6 pH) while pH in water is 5.92 pH.

Soil adsorption complex according to Kappen, i.e. cation exchange capacity T, is 9.15 mmol/100 g, whereas the optimum is 15.0 mmol/100 g.

Summarizing soil analyses one can say that pedological conditions are typical of the Central Bohemian region with a low level of nutrients but good physical aspects.

Climatic conditions are good with average year temperature of about 8°C. Vegetation period lasts for 163 days. Annual precipitation amount is about 635 mm. Detailed information on precipitation during the vegetation period is given in Table 1.

Research plots were planted with Silver fir two-years-old bare root seedlings in 1999. Three different types of fertilizers were used: two are of the same trademark but of different consistency which may influence the availability of nutrients to the root system. The fertilizer was added to the root in a hole when the seedling was planted. A dose (granules, tablets or powder) was added to each seedling when planted. The dose was calculated so that the nitrogen content of different treatments would be compatible. The details are given in Table 2.

The sequence of research plots in the field is:

1. conventional fertilizer, represented by Cererit granules,
2. fertilizer pills, represented by Silvamix MG in tablets,
3. powder fertilizer of the same composition as pills,
4. control where no fertilizer was used.

All research plots are alongside each other in the above given order. Seedlings were planted in rows. There are about 9 saplings in each row, which makes four to nine rows per each plot depending on the number of seedlings and space available. Basic information on research plots is given in Table 3.

Tree heights were measured at the end of vegetation period in the years 2000 to 2003. The height was measured as a distance between the ground plane and the horizontal plane projected at the highest living end of the plant to the nearest 0.5 cm. Collar diameter was measured at the ground level to the nearest 1 mm.

Table 3. Description of research plots, used fertilizers and number of plants per plots

Plot identification	Type and name of fertilizer	Dose of fertilizer per plant	Number of plant
1 conventional	Cererit	55 g	35
2 pills	Silvamix MG	4 × 10 g pill	50
3 powder	Silvamix MG	40 g	50
4 control	No fertilizer	0 g	80

Table 4. Height growth in cm of Silver fir plants in the year 2000–2003

Plot identification	2000	2001	2002	2003
1 conventional	54.2	94.9[a]	152.1[a]	210.8[a]
2 pills	54.1	97.6[a]	145.5[a]	210.2[a]
3 powder	56.9	99.2[a]	146.9[a]	213.4[a]
4 control	49.1	76.1	115.2	176.6

[a]Denotes significant difference at the level 95% when compared to control plot

The apical dominance ratio (Grassi et al. 2004) was determined by measuring the length of the leading sprout and the mean length of the lateral branches at the first node of each sapling. The apical dominance ratio (ADR) is a good indicator of sapling vigour. ADR is considered as more informative than height increment (both absolute and relative). Saplings which have ADR lower than one or close to one are under stress (nutrient or light or both deficiencies) and they are going to die if their environmental conditions do not improve soon.

RESULTS AND DISCUSSION

So far the data have shown a positive reaction of Silver fir in height increments to site amelioration. This positive reaction is important namely for this early slow growing species as it enables better weed control. Weed competition is one of the most important harmful factors for Silver fir seedlings. The faster height increment is also important because it helps prevent game browsing damage which is a serious problem in Czech forest management (Lajtner 1999).

Bare-root plants and seedlings suffer from so called "planting shock" one or several growing seasons after planting (Kotrla 1999). The reasons of this phenomenon are insufficient supplementation of water and nutrition by the root system which is unable to get these sources from the soil liquid on an adequate level. When the root contacts with soil are re-established, water and nutrient statuses in plant tissues are improved and plant restores its height and diameter growth. The enrichment of nutrient supplementation by fertilizer usually improves height growth with some delay. Different species also react to nutrient supply differently.

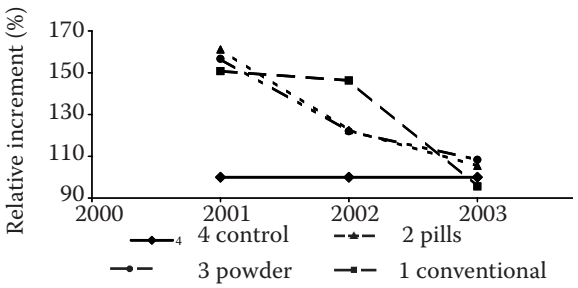

Fig. 1. Relative height increments on research plots (increment on the control plot is considered as 100% each year)

Silver fir plants seem to exhibit a reaction to nutrient enrichment immediately in the first year after fertilization, however the differences are not statistically significant. Height growth data for the time span 2000–2003 are given in Table 4.

While in the first year (2000) the differences between plants on the plots were not significant at the level 95%, in the following years clear differences in height increment were pronounced at the statistical level of 95%. Positive reactions to fertilizer started to be manifested since 2001 surprisingly a bit more for Silvamix powder (3) and pills (2) rather than for conventional NPK fertilizer (1). Although Silvamix is declared to be a slow-acting source of nitrogenous nutrition with delay impact on plants, the results on our research plots show better height increment quite soon (Table 4). But differences are significant only when they are compared to the control plot, not between fertilized plots 1 to 3. That means the conventional fertilizer (N1) did not have a substantially greater influence on height increment than slow-acting fertilizers.

There was no frost damage on saplings proving the nitrogen dose was not too high. No immature terminals were found on research plots.

We can see the height growth reaction more precisely if we calculate relative height increment. Increments on control plots each year serve as a basis for the calculation. The relative height increments on research plots with fertilizer pills (N2) and with conventional fertilizer (N1) were a bit lower in 2001 – but not significantly (Fig. 1). The situation was reversed in 2002, when the plot with conventional fertilizer (N1) was better than the other plots with other types of fertilizers (N2, N3) (Fig. 1). Finally, the relative increment decreased in 2003 (4 years after application). The fastest or largest decrease occurred in trees growing on the plot with conventional fertilizer (N1), which in terms of relative increment was lower than those in the

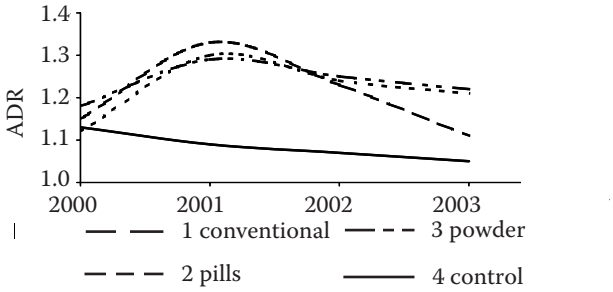

Fig. 2. Changes of the apical dominance ratio on research plots in 2000–2003

control. But these differences between saplings influenced by fertilizers were again not significant.

To conclude the slow-acting fertilizers really showed a slow release of nutrients which was evident in the third year (2002) after application whereas in the other years the height increments were quite similar. It should be stressed that although small differences were evident, they were not significant. On the other hand, there were significant differences between height increments of trees on fertilized plots and on the control plot, i.e. on the plot without any fertilizer. The differences in terms of relative increment were between 120 and 150%!

Relative height increments decreased in the fourth year after fertilizer application. But at that time the differences in absolute height were about 30 cm in favour of trees on fertilized plots. These differences are important for the survival of Silver fir saplings after planting in the forest.

The apical dominance ratio (ADR) was determined by measuring the length of the leading sprout and the mean length of the lateral branches at the first node of each sapling each year. The value lower than 1.0 belongs to trees under environmental stress (deficiency of nutrients and/or light). The highest ADR is the highest increment of leading sprout, which is an evidence of good growing status and suitable environment for the tree.

The changes of ADR can be seen in Fig. 2. It seems that the ADR variable is appropriate to reflect the height increment as a result of nutrient status and environmental conditions of young trees. The fertilized trees on research plots have significantly higher ADR (the value between 1.2 and 1.3) while trees on the control plot (without fertilizers) have the ADR values around 1.0.

A decrease of ADR by the year 2003 depicts evidently the drop of fertilizer influence on height growth.

CONCLUSIONS

From the aspect of the target species composition in Czech forests Silver fir (*Abies alba* Mill.) is considered as one of the important species that should be reintroduced into the stands. However, Silver fir as a climax species is not an "easy" one for reforestation especially on bare soils after clear cutting. Seedlings and saplings are vulnerable and threatened by many harmful factors such as weed competition and game browsing to name a few. One of the possible solutions for this difficult target is the use of fertilizer to stimulate Silver fir growth in order to shorten the period when the species could be damaged or even destroyed.

Three different fertilizers were used on trial plots. The first is called "conventional" as it is a common industrial fertilizer widely used in this country. The others belong to "new" types of industrial chloride-free fertilizers providing slow-acting sources of nutrients. The details about the used fertilizers are given in Table 2.

The preliminary data shows that fertilizers could improve height growth of Silver fir in a statistically significant way. In the second year after fertilizer application the height increment was by 50% higher than the increment on the control plot. This positive increase lasted for the next two years with a smaller but still significant increase. The basic data on height growth of Silver fir saplings are given in Table 4. Although Silvamix fertilizer as the representative of a new type of fertilizer is declared to be a slow-acting source of nitrogenous nutrition with delay impact on plants, the results on our research plots show better height increments quite soon.

When we compare increments on different plots with increment on the control plot where no fertilizer was used (as a reference plot), we could see a more highlighted picture. The relative height increments on research plots with fertilizer pills (N2) and with conventional fertilizer (N1) were a bit lower in the year 2001 – but not significantly (Fig. 1). The situation was reversed in 2002, when the plot with conventional fertilizer (N1) was better than the other plots with other types of fertilizers (N2, N3) (Fig. 1). Finally, the relative increment decreased in 2003 (4 years after application). The fastest or largest decrease occurred in trees growing on the plot with conventional fertilizer (N1), which in terms of relative increment was lower than in the control. But these differences were not significant again.

To conclude the slow-acting fertilizers really showed a slow release of nutrients which was evident in the third year (2002) after application whereas in the other years the height increments were quite similar. It should be stressed that although small differences were evident, they were

not significant. On the other hand, there were significant differences in height increments of trees between fertilized plots and control plot, i.e. without any fertilizer. In terms of relative increment the differences were between 120 and 150%! There was no frost damage on saplings proving the nitrogen dose was not too high. No immature terminals were found on research plots.

The recommendation for Silver fir planting could be drawn up from this data in the form of application of fertilization in the year of planting at a "normal dose" – the content given in Table 2 could serve as an example of normal dose with possible repetition in the third or fourth year after planting.

The apical dominance ratio was used as an auxiliary variable to assess the growth status of seedlings and saplings. Fig. 2 shows quite noticeable and promising results which deserve more attention and field observations in the future to judge the quality of the new variable.

It seems that the ADR variable is suitable to reflect the height increment as a result of nutrient status and environmental conditions of young trees. The fertilized trees on research plots have significantly higher ADR (1.2–1.3) while trees on the control plot (without fertilizers) have the ADR values around 1.0.

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Reakce výsadeb jedle bělokoré (*Abies alba* Mill.) na hnojení

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ABSTRAKT: Jedle bělokorá je důležitou dřevinou našich lesů. Její nedávné hromadné odumírání dramaticky snížilo její zastoupení v lesích střední Evropy. Reintrodukce této dřeviny není snadná, protože je to dřevina, která je citlivá k nepříznivým vnějším podmínkám a značně trpí škodami zvěří. Hnojení výsadeb jedle může zkrátit období nejvyšší citlivosti této dřeviny ke škodám a tím zvýšit ujímavost těchto kultur. Pokusné plochy s jedlí byly založeny v roce 1999. Na výzkumných plochách se zejména sleduje vliv různých typů hnojiv na výškový růst a přírůst této dřeviny. K hodnocení úspěšnosti obnovy lesa touto dřevinou byla použita i apikální dominance jako nová charakteristika vitality a růstu mladých sazenic a odrůstajících kultur.

Klíčová slova: jedle bělokorá; meliorace stanoviště; druhové složení; obnova lesa; apikální dominance

Jedle bělokorá byla důležitou jehličnatou dřevinou v našich lesích a z hlediska přirozené druhové skladby byla dokonce naším nejrozšířenějším jehličnanem. Její zastoupení se v původní druhové skladbě odhaduje na 18 %, zatímco dnes zaujímá plochu menší než 1 %. Existuje řada hypotéz a pokusů vysvětlit tento dramatický ústup jedle z našich lesů. Důležitější než hledání tohoto důvodu je ale skutečnost, že postupně dochází k revitalizaci jedle a tím i roste možnost její reintrodukce do našich lesů. Jedle má mohutný kořenový systém a je proto řazena mezi „dřeviny meliorační a zpevňující", jejichž minimální podíl je předepsán lesním zákonem. Jedle je však dřevinou, která je značně citlivá na nepříznivé vnější podmínky, a proto se velmi obtížně obnovuje na holé ploše. Je také značně citlivá ke škodám zvěří, která ji bohužel vyhledává. K úspěšnému opětnému zavedení jedle do našich lesů je tedy žádoucí co nejvíce zkrátit období kultur, kdy je jedle vystavena zmíněným škodám. Jednou z možností je hnojení, které podpoří zejména výškový růst jedle.

Na školním lesním podniku České zemědělské univerzity v Praze byly v roce 1999 založeny výzkumné plochy s jedlí. Základní přírodní podmínky lze charakterizovat jako typické pro středočeskou oblast, a to jak z hlediska půdních podmínek a stavu živin v těchto půdách, tak i klimatických podmínek. Rozložení srážek ve vegetačním období uvádí tab. 1.

Cílem výzkumu je:

– analyzovat reakci sazenic jedle bělokoré na různá hnojiva,
– formulovat doporučení pro používání hnojení při výsadbách jedlových kultur.

Celkem byly použity tři typy hnojiva, přičemž Silvamix MG byl aplikován jako prášek či jako tablety. Podrobnosti o složení použitých hnojiv uvádí tab. 2. Byly založeny čtyři pokusné plochy – pro každý typ hnojiva jedna plocha plus kontrola. Hnojiva byla aplikována do jamky v okamžiku výsadby, přičemž byly použity dvouleté prostokořenné neškolkované semenáčky. Podrobnosti o jednotlivých plochách uvádí tab. 3.

Výsledky jednoznačně potvrzují pozitivní efekt všech typů hnojiv na výškový růst jedle bělokoré. Všechny hnojené plochy měly signifikantně vyšší průměrnou výšku sazenic od roku 2001, přičemž při posledním měření (v roce 2003) byl už rozdíl mezi kontrolou a průměrnou výškou hnojených kultur více než 30 cm (podrobnosti uvádí tab. 4). Zajímavé je srovnání jednotlivých variant pokusů z hlediska jejich relativního výškového přírůstu. V roce 2001 byl relativní přírůst o 50 % vyšší u všech hnojených variant, přičemž rozdíly mezi jednotlivými variantami nebyly signifikantní. V následujícím roce (tedy tři roky po aplikaci hnojiva) se výrazněji projevil efekt klasického normálně rozpustného hnojiva oproti pomalu účinkujícím hnojivům typu Silvamix. V dalším roce se situace obrátila, i když rozdíly nebyly signifikantní.

Zajímavou veličinou, která má zřejmě dobrou vypovídací schopnost o růstu a vitalitě semenáčků a sazenic, je apikální dominance (Grassi et al. 2004). Jak je patrné z obr. 2, účinek hnojiva na průběh této veličiny je více než významný a dobře patrný.

Z dosud získaných výsledků je zřejmé, že použitá dávka hnojení, která byla aplikována při výsadbě jedle bělokoré, má signifikantně významný vliv na výškový přírůst této dřeviny a je tedy účinným prostředkem ke zkrácení období, kdy je tato dřevina vystavena nepříznivým vlivům, jež mohou být příčinou neúspěchu při její obnově.

Závěry pro obnovu jedle lze tedy shrnout do tří zásad:

Použité jednorázové dávky hnojiva (detaily v tab. 2) při výsadbě jsou dostatečné k tomu, aby významně zvýšily výškový přírůst jedle.

Použité dávky dusíku nebyly příliš vysoké, aby vedly k nedostatečnému vyzrání letorostů a tedy ke škodám mrazem.

Účinek hnojiva odezní kolem čtvrtého roku po aplikaci, a to je tedy vhodná doba k opakování hnojení, pokud chceme zvýšený přírůst udržet.

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