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ORIGINAL ARTICLE

Effects of slow-release fertilizers of Silvamix and Silvagen line on growth of a young spruce and larch forest plantation three years after application

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Abstract

This work evaluates effects of tablet fertilizers Silvamix, Silvamix Mg and Silvagen on height and diameter growth of a young plantation of Norway spruce [*Picea abies* (L.) Karst.] and European larch (*Larix decidua* Mill.) after the third year of fertilizer application. The experiment was conducted on one experimental plot in the Low Tatra Mountains. The fertilizers were applied at a rate five tablets (50 g) per each tree, considering not treated trees as the control. The tablets were laid on the ground and thoroughly trodden into soil. ANOVA analysis did not reveal any significant effects of fertilizers on height and diameter growth of Norway spruce trees. The use of Silvagen resulted in significant effects on height growth of larch trees.

Key words

tablet fertilizer, height increment, diameter increment, forest plantation, Silvamix, Silvagen

Introduction

Slow-release fertilizers have been used for many years in forest practice. Gradual release of nutrients into soil is their added benefit. Nutrient release from fertilizers depends not only on soil chemistry, its biological activity and water regime but also on plant chemotropism. Nutrients can be utilized by plants in course of several growing seasons. Limited solubility of nutrients and a high degree of their uptake by plants prevent their excessive dissolution in soil and surface waters.

Forest fertilizers of Silvamix line have been developed from 1983, and application of side-dressing in forest plantations in the areas threatened by air pollution and calamity was the first purpose of this fertilizer utilisation. Reforestation of these localities was very difficult, thus research was initiated with the aim to support young tree plantation growth in such extreme conditions.

Nárovec (2004) suggests that tablet fertilizers present a new way of fertilization. The purpose of fertilization of this kind is long-term nutrient supply with the use of a slow-release industrial fertilizer. In general, fertilization is an important operation for providing nutrition to cultivated plants with the objective to intensify their growth as well as increase their vitality and resistance against a whole range of stress factors. Slow-release fertilizers enable to simplify the system

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of plant nutrition because the overall dose of nutrients can be applied into the substrate at the beginning of the growing season without any risk of excessive supply of nutrients. Above all the application of slow-release fertilizers is important in young stands just after their establishment because the first supplement of necessary nutrients takes place during the most critical period, i. e. after planting and during the period of initial growth and development of the root system. In case of tree species, this critical period can last several years and first of all it depends on local climatic conditions. It is quite clear that after planting it is not possible to assure better care and growing conditions for young trees than in a forest nursery.

The purpose of this paper was to evaluate effects of slow-release fertilizers on height and diameter growth of young forest plantation.

Materials and methods

In the locality Vápeniar (20°01´ E, 49°02´ N) (the Low Tatras Mountains), an experimental plot was established in the stand 88 C. The experimental plot had a rectangular shape of the size about 40 x 50 m. The habitat type of the analysed stand is Acidophilous silver fir forest and the site consists of forest types, which are presented in Table 1. The aspect is north-east, the slope is 40% and the altitude is about 950 m a.s.l.

The stand represents a young forest plantation, 3 years old, consisting of the Norway spruce [*Picea abies* (L.) Karst.] and European larch (*Larix decidua* Mill.). The trees were planted at the age of three years and then raised through lining out (transplanting). The trees were planted with the use of hole planting with plant spacing of about 2 m. The trees were treated with tablets of fertilizers Silvamix, Silvamix Mg and Silvagen. The fertilizers were applied at a rate five tablets (50 g) per tree repeated from one tree to another. This number of tablets corresponds to the instruction for application of tablet fertilizers recommended by the producer. Individual fertilizers were regularly altered from one tree to another. Control trees were not treated. The tablets were laid on the ground and thoroughly trodden into soil. A thin layer of top-soil was removed using a small hoe in order to better lay and fix tablets in soil. Then tablets were covered back with stripped top soil, and packed down in order to be firmly fixed in top-soil. A distance of the tablets from seedling stems corresponded to the perimeter of seedling vertical projection onto the soil surface. The tablets were not placed closer than 15 cm from seedling stems. The distance did not exceed outer limits of seedling vertical projection by more than 10 cm.

Tree height (the total length of plant shoot) and tree diameter at the root collar were measured for both studied tree species at the time of fertilizer application (May 2006) and then at the time when the growing season finished (October 2006, October 2007 and October 2008). ANOVA was used for comparison of fertilizer effects on tree growth. Before using ANOVA, normality of data distribution was assessed. STATISTICA 7 software (StatSoft®) was used for data analyses

Results and discussion

Biometrical parameters of the fertilized plantation are shown in Table 2. During the three years of observations the larch forms substantially higher increments in situ. The height increments are 2–7 times higher and the diameter increments are 2–2.5 times higher than those observed in the spruce.

Tab. 1. Habitat classification of analysed stand

Stand area (%)	Forest type according to Slovak forest typology		CORINE[1]		Pal. Hab.[2]	
	Code	Name	Code	Name	Code	Name
90	6124	Bilberry-spruce with fir of higher degree	42.1	Fir forests	42.13	Acidophile medio-European fir forests
10	5126	Podzolic-spruce with fir of lower degree	42.1	Fir forests	42.13	Acidophile medio-European fir forests

[1] According to the classification of Commission of European Communities

[2] According to the Palaearctic Habitat Classification

Tab. 2. Biometrical parameters of fertilized plantation

Period	Parameter	Species/fertilizer							
		Spruce				Larch			
		Silvamix	SilvMg	Silvagen	Control	Silvamix	SilvMg	Silvagen	Control
Spring 2006	number of measured trees	62	62	62	62	61	66	62	62
	tree height (cm)[1]	36.15	36.12	36.61	37.05	51.97	50.71	52.65	50.94
	tree diameter (mm)[1]	7.72	7.91	7.76	7.82	8.98	8.71	9.05	8.76
Autumn 2006	number of measured trees	61	57	61	56	57	63	58	59
	tree height (cm)[1]	39.33	38.54	38.83	39.87	63.26	65.24	69.63*	59.59*
	tree diameter (mm)[1]	9.50	9.82	9.62	9.26	12.84	13.00	13.90*	11.92*
Increment 2006	height increment (cm)[2]	3.18	2.41	2.21	2.82	11.30	14.53	16.98	8.66
	diameter increment (mm)[2]	1.78	1.92	1.86	1.44	3.87	4.29	4.85	3.15
Autumn 2007	number of measured trees	56	56	58	54	55	64	56	59
	tree height (cm)[1]	50.04	51.60	51.72	50.39	90.11	94.59	102.76*	83.08*
	tree diameter (mm)[1]	13.20	13.50	13.90	13.17	20.85	21.59	22.82*	18.68*
Increment 2007	height increment (cm)[2]	10.71	13.06	12.89	10.52	26.85	29.35	33.13	23.49
	diameter increment (mm)[2]	3.70	3.68	4.28	3.91	8.01	8.59	8.92	6.76
Autumn 2008	number of measured trees	51	52	54	52	51	59	48	55
	tree height (cm)[1]	63.69	65.17	65.74	64.87	126.27	122.82	139.98*	114.60*
	tree diameter (mm)[1]	17.56	18.33	18.29	17.61	27.93	28.02	29.98	25.73
Increment 2008	height increment (cm)[2]	13.65	13.57	14.02	14.48	36.16	28.23	37.22	31.52
	diameter increment (mm)[2]	4.36	4.83	4.39	4.44	7.08	6.43	7.16	7.05

[1] arithmetic mean

[2] difference between values of arithmetic means between two measured periods

* statistically significant difference between compared pairs (tested on a 5% level of significance)

Effects of fertilizers on spruce growth

Table 3 and Figure 1 present the effects of fertilization on height growth of spruce trees after the third year of experiment.

Surprisingly, it was found the highest height increment in control spruces. The lowest height increment was observed in spruce trees treated by Silvamix Mg (2008 increment). The highest mean value of spruce trees height was found in spruces treated with Silvagen. The lowest mean value of spruce height was found in trees treated with Silvamix. The differences are statistically insignificant (Tab. 3). ANOVA did not confirm statistically significant effects of fertilizers on spruce height growth. Remeš *et al.* (2005a) reports that tablet fertilization stimulated height growth of young trees in the year immediately following application of fertilizers, i.e. in the second vegetation season.

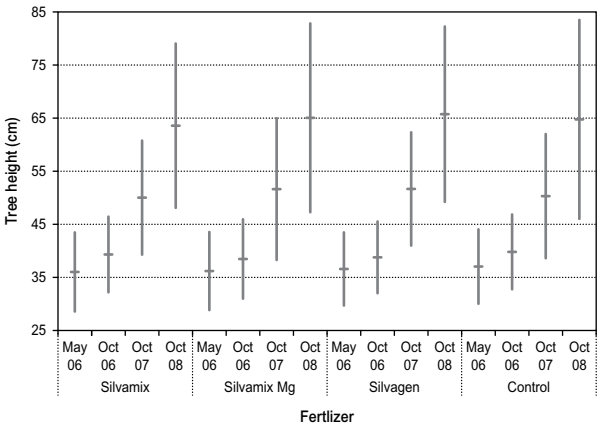

Fig. 1. Biometrical parameters of spruce height (mean ± standard deviation)

Tab. 3. Fertilization effect on spruce height growth assessed by ANOVA

Groups	Count	Average	Variance			
Silvamix	51	63.69	244.74			
Silvamix Mg	52	65.17	327.48			
Silvagen	54	65.74	282.81			
Control	52	64.87	361.34			
ANOVA						
Source of Variation	SS	df	MS	F	F crit	P-value
Between Groups	117.2	3	39.05	0.128	2.649	0.943
Within Groups	62355.9	205	304.18			
Total	62473	208				
Inference	insignificant					

For more than three years Szoltyk (2004) evaluated effects of NPKMg fertilizers on spruce young forest cover. She reports that the total height increment was by 143% higher in treated spruces in comparison with control trees.

Table 4 and Figure 2 present the effects of fertilizers on diameter growth of spruce trees. The highest diameter increment was found in spruce trees treated with Silvamix Mg. On the other hand, the lowest diameter increment was observed for spruces treated with Silvamix. The highest mean diameter value in spruce trees was found for spruces treated by Silvamix Mg. The lowest mean value of spruce diameter was found for spruces treated by Silvamix. The differences are statistically insignificant (Tab. 4). ANOVA did not con-

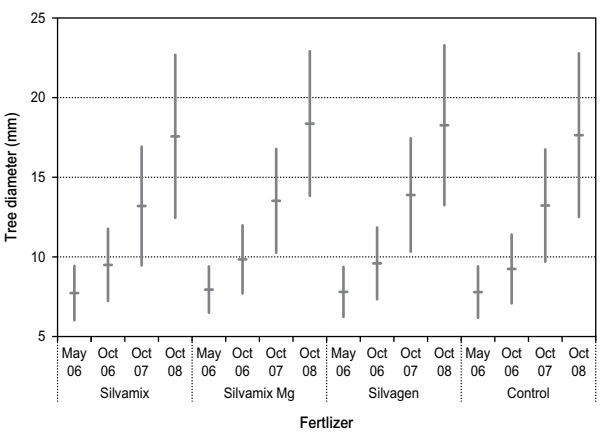

Fig. 2. Biometrical parameters of spruce diameter (mean ± standard deviation)

Tab. 4. Fertilization effect on spruce diameter growth assessed by ANOVA

Groups	Count	Average	Variance			
Silvamix	51	17.56	27.31			
Silvamix Mg	52	18.33	21.16			
Silvagen	54	18.29	25.56			
Control	52	17.61	27.16			
ANOVA						
Source of Variation	SS	df	MS	F	F crit	P-value
Between Groups	28.00	3	9.33	0.369	2.649	0.775
Within Groups	5184.18	205	25.29			
Total	5212.18	208				
Inference	insignificant					

firm any statistically significant effects of fertilizers on spruce diameter growth.

These results do not confirm the results of Tučeková and Sarvaš (2002) who report positive effects of fertilization on seedlings growth after one year of fertilizer influence. On the contrary, Kubíček (2003) mentions that tablet fertilization using Silvamix and Silvamix Mg significantly impacted relative height and diameter growth of spruce seedlings in the second year of the experiments

Effects of fertilizers on larch growth

Table 5 and Figure 3 present the effects of fertilization on height growth of larch. It was found the highest height increment in larch trees treated with Silvagen (37 cm during the summer period 2008). The lowest height increment was observed in larch trees treated with Silvamix Mg (only 28 cm during the period of summer 2008). The highest value of mean tree height was indicated in larch trees treated with Silvagen. The mean value of tree height was by 25 cm lower in control larches (Fig. 3). After the third year, ANOVA analyses confirmed significant effects of Silvagen fertilizer on annual height growth of larch trees in comparison to control trees (Tab. 5). Also it was found significant effects of Silvagen fertilizer on larch height

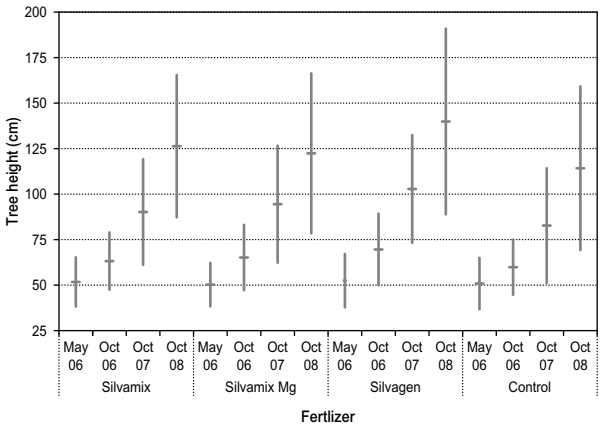

Fig. 3. Biometrical parameters of larch height (mean ± standard deviation)

Tab. 5. Fertilization effect on larch height growth assessed by ANOVA

Groups	Count	Average	Variance			
Silvamix	51	126.27	1552.96			
Silvamix Mg	59	122.82	1990.60			
Silvagen	48	139.98	2688.35			
Control	55	114.60	2083.10			
ANOVA						
Source of Variation	SS	df	MS	F	F crit	P-value
Between Groups	17048.8	3	5682.93	2.750	2.648	0.044
Within Groups	431942.7	209	2066.71			
Total	448991.5	212				
Inference	**significant**					
Matched comparison of pair samples						
Scheffe`s Test						
Comparative pairs	Inference	Probability				
Silvamix – Silvamix Mg	insignificant	0.984				
Silvamix – Silvagen	insignificant	0.524				
Silvamix – Control	insignificant	0.628				
Silvamix Mg – Silvagen	insignificant	0.290				
Silvamix Mg – Control	insignificant	0.818				
Silvagen – Control	**significant**	0.049				

increment back in the first and the second year after fertilization.

Similarly, Remeš *et al*. (2004) analysed effects of Silvamix (powder) and Silvamix Forte (tablets) on the height increment of grand fir (*Abies grandis* Lindl.) seedlings. The authors found statistically significant effects on tree height after the first year of fertilizer influence. These results can be caused by a big share of nitrogen (56% of the total nutrient amount) in Silvagen.

The highest diameter increment was found in larch trees treated with Silvagen (7.16 mm during the growing season 2008). The lowest diameter increment was found in larch trees treated with Silvamix Mg (6.43 mm during the growing season 2008) (see Tab. 2). The highest mean value of diameter was observed in larch trees treated with Silvagen. The lowest mean value of root collar diameter was found in control larches (Fig. 4). Table 6 presents effects of fertilizers on larch diameter growth. When compared with control trees three years after fertilizer treatment, no statistically significant effects of fertilizers on larch diameter growth were found. However, significant effects of Silvagen fertilizer on diameter growth were observed in the first and second year after fertilization.

Sarvaš, Tučeková, Pavlenda (2003) found a positive effect of Silvamix Mg fertilizer on the height increment of beech in the first year after fertilization. Walker (2005) compared three fertilizer formulas with high N content in a plantation of the Jeffrey pine (*Pinus jeffreyi* Grev. et Balf.). The fertilizers were applied by dispersion three years after plantation establishment. It was found that, in total fertilization increased tree height by 143%, and stem diameter by 104% after five growing seasons.

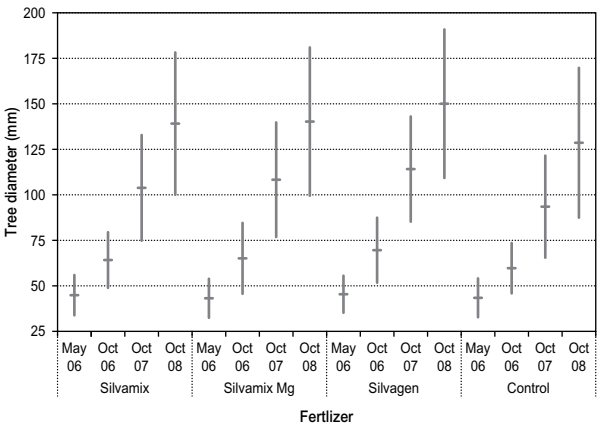

Fig. 4. Biometrical parameters of larch diameter (mean ± standard deviation)

Overall evaluation of fertilizer effects on tree growth

The main contribution of this paper is ascertaining effects of Silvagen fertilizer on height and diameter growth in larch trees in the first and second year after fertilization. The effect on height growth of larch trees carries over in the third year after fertilization in comparison to control larches. There were no significant effects of other fertilizers tested on tree growth. Although, significant effects of other fertilizers on tree

Tab. 6. Fertilization effect on larch diameter growth assessed by ANOVA

Groups	Count	Average	Variance			
Silvamix	51	27.93	63.14			
Silvamix Mg	59	28.02	69.35			
Silvagen	48	29.98	70.06			
Kontrola	55	25.73	70.10			
ANOVA						
Source of Variation	SS	df	MS	F	F crit	P-value
Between Groups	467.96	3	155.99	2.279	2.648	0.081
Within Groups	14305.4	209	68.45			
Total	14773.4	212				
Inference	insignificant					

growth in the second and third year was expected in comparison to control trees. Sarvaš, Tučeková, Pavlenda (2003) carried out detailed investigations on Silvamix Mg fertilizer application. In the second year after fertilization, the authors found differences in favour of spruce trees treated with fertilizers, and they expect the confirmation of statistical significance in subsequent years. Similarly, Remeš *et al*. (2005b) found that tablet fertilization with the use of Silvamix and Silvamix Mg contributed to the height increment in spruce seedlings in the second year after fertilizer treatment. The authors state that the positive effect of tablet fertilizers on plantation height growth persists in some cases in the third and the fourth year after fertilization.

However, Kuneš, Balcar, Čížek (2004) carried out observations for the period 9 years after application of Silvamix Forte tablet fertilizer to spruce trees growing in air polluted sites. They found that spruce trees treated with Silvamix fertilizer showed a significantly faster rate of height growth than control trees over the period from 1997 to 2000. Similarly, in 2002 the average stem base diameter of Silvamix treated variant was by 12.5% larger than that of the control.

Conclusion

Based on the results the use of Silvagen fertilizer in forestry practice is recommendable. The significant positive effect of Silvagen fertilizer on growth of treated larch trees in comparison to control ones. On the other hand, there were no statistically significant effects of other fertilizers tested (Silvamix and Silvamix Mg) on tree growth, however trees treated with these fertilizers manifested somewhat greater height and diameter increments in comparison to not treated trees. In order to obtain reliable conclusions, it would be necessary to conduct economic and ecological evaluations of fertilizers applied in forest young plantations, but this was not the purpose of present study. It is necessary to carry out extensive research taking into account a range of different conditions reported by multitude of research studies. Present partial work attempted to contribute to the discussion on effectiveness of tablet fertilizers application with regard to growth of forest young plantations.

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