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Production of Norway spruce (*Picea abies* [L.] Karst.) seedlings on substrate mixes using growth stimulants

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ABSTRACT: We evaluated the growth of Norway spruce (*Picea abies* [L.] Karst.) seedlings on peat and bark substrates, on their mixes and on their mixes with agroperlite. We examined the basic quantitative traits (seedling diameters and heights), the number of produced seedlings per unit area, main root lengths, number of axial shoots and dry weight of shoots and roots. Besides the study of substrate influence on the biometrical characteristics of seedlings applied standard fertilisation an experiment was established as the second variant where the effect of biostimulants was tested; they were supplied by the JAMINEX Company. The experiment was established with three replications by standard technologies used in forest operations. A conclusion can be drawn that in our experiments peat was found to be the most suitable substrate for production of Norway spruce seedlings. Positive effects of biostimulants were highly significant on almost all tested substrate mixes.

Keywords: Norway spruce seedlings; substrates and their mixes; biostimulant treatment

An increasing demand for the quantity and quality of planting stock highly influences nursery production and associated nursery technologies. Production of seedlings on substrates is a technology that can be considered as optimum from the aspect of nursery production effectiveness (seed savings, shortening of production time, increase in production safety). In general, peat is the most frequently used and the most effective substrate in nursery production.

But peat reserves are largely limited, especially in Slovakia. Therefore other suitable materials are sought that could replace it or reduce its consumption at least. Substrates made of wood waste and so called combined substrates composed of organic and inorganic materials seem to be a good idea.

Many authors investigated seedling growth on mixed peat-bark substrates (Bluďovský 1975; Fencl 1977; Mauer 1978, 1988; Chalupa 1981; Lipták, Saniga 1982; Saniga 1985; Dušek 1989; Slávik 1988, 1990, 1991, 1993; Demko, Šmelková 1994). Most authors reported that the best results were achieved on pure peat substrates or on mixtures with their highest possible percentage proportion.

Repáč (1996, 1999, 2000a,b) and Repáč and Slávik (1997) studied the improvement of conditions of spruce seedling growth on substrates by artificial mycorrhisation while Řeťovský (1953) and Havranová (1999) evaluated the influence of biostimulants on seedling growth.

The objective of this paper was to contribute to the knowledge of substrate technologies for Norway spruce seedling production by testing growth on combined organic and inorganic substrates and by applications of growth biostimulants and to provide specific findings to improve the production of this tree species.

MATERIAL AND METHOD

Site of experiment establishment and its description

An experiment with the production of Norway spruce seedlings on tested substrates was conducted in 2002. A research object of Forestry Research Institute, Veľká Stráž Biological Base, which lies about 3 km north-west of the town of Zvolen, was chosen as a site for experiment establishment. A research plot is situated in the geographical area Zvolenská kotlina at an altitude of 320 m above sea level, its gradient is maximally 5%. Average annual temperatures are 7–8°C, and 13–14°C in the

Table 1. Chemical composition of substrates

Substrate	$pH\text{-}H_2O$	pH-KCl	Humus (%)	C (%)	N (%)	C/N	Nutrients available (mg/kg)	
							P	K
P	5.72	5.57	63.34	36.7	1.55	23.70	486	3,994
B	7.35	7.07	28.05	16.3	0.88	18.50	201	766
P + A	5.43	5.11	33.31	19.3	0.83	23.20	146	490
B + A	7.36	7.13	26.43	15.3	0.77	19.90	134	317
P + B	7.18	6.87	36.65	21.3	0.86	24.80	201	1,237
P + B + A	6.75	6.58	35.69	20.7	0.80	25.90	161	479

growing season. Average number of summer days is 40, the number of frost days per year is 50. Annual precipitation sum amounts to 650–700 mm; of this sum 350–400 mm falls per growing season. Climatic data were taken over from the nearest meteorological station Sliač.

Seed description

Seed samples were received from the Semenoles Company at Liptovský Hrádok; seed originated from Slovenská Ľupča Forest Enterprise, stand No. 224c, seed lot 34/1/89 (Ľubietovský Vepor area). Seed quality was tested by workers of the Seed Control Division of Forestry Research Institute at Liptovský Hrádok Research Station. Seed purity was 92% and average germination rate 87%. The seed satisfied the requirements for quality class I and therefore it was suitable for testing.

Description of tested substrates

Basic components of tested substrates were two organic materials (peat P, spruce bark compost B) and one inorganic material (agroperlite A). These materials were combined at identical percentages by volume to produce experimental mixes: (P + A) – peat and agroperlite, (B + A) – spruce bark compost and agroperlite, and (P + B + A) – a mix of peat, spruce bark and agroperlite containing a third portion of each component. Brief characteristics of the used materials are as follows:

– Peat (P) – dry upland, enriched with nutrients of one-component mineral fertilisers, trademark Lesnícky substrát
– Spruce bark compost – ca. 100 m^3 of crushed spruce bark, 10 m^3 of soil, 1 t of ground limestone, 0.5 t of urea, 0.5 t of superphosphate, ripening time 1 year

Table 2. Growth characteristics of Norway spruce seedlings grown on substrates with or without biostimulants (P – peat, B – bark, A – agroperlite, BS – biostimulants)

Substrate	Sowing recovery (%)	Stem height (mm)	Root length (mm)	Root collar diameter (mm)	Dry weight of (mg)		Number of short roots (ROOT/cm)	Number of lateral shoots
					shoots	roots		
P	77.7	82.8	215.9	2.04	431	222	4.67	1.80
P with BS	85.3	87.0	194.9	2.78	515	263	5.47	3.73
Significance	**	*	**	**	N	*	**	**
B	56.3	38.9	165.6	1.26	127	76	7.85	0.00
B with BS	70.7	39.4	170.8	1.38	173	85	8.36	1.20
Significance	**	N	N	**	**	N	**	**
P+A	80.3	69.5	230.2	1.81	322	189	4.97	0.63
P+A with BS	86.3	73.6	235.0	2.30	502	240	6.39	2.47
Significance	**	**	N	**	**	**	**	
B+A	63.0	58.1	253.3	1.58	173	134	6.54	0.53
B+A with BS	66.3	62.3	207.2	1.58	302	161	7.66	2.23
Significance	N	**	**	N	**	*	**	**
P+B	73.0	58.7	230.5	1.60	127	106	6.84	1.07
P+B with BS	79.0	64.9	219.9	2.35	217	208	7.91	3.33
Significance	N	**	N	**	**	**	**	**
P+B+A	76.0	65.3	253.8	1.84	164	130	4.82	1.33
P+B+A with BS	83.0	61.8	241.7	2.29	228	171	6.33	2.73
Significance	**	**	N	**	**	**	**	**

Significance: N – statistically not significant, * – statistically significant, ** – statistically highly significant

– Agroperlite (A) – granular expanded perlite. It is a volcanic glass that largely increases its volume at a temperature of about 1,000°C, so its initial bulk density is not higher than 200 kg/m^3. A fraction of grain size 4–8 mm was used for tests.

Table 1 shows the chemical composition of tested substrates. Analyses were carried out in laboratories of the company Lesoprojekt Zvolen.

Description of tested biostimulants

Effects of liquid, ecologically sound biostimulants on the basis of synthetic amino acids were tested in our experiments. These biostimulants were supplied by the Spanish-Czech company JAMINEX.

Experiment establishment and conduct

Experiments were conducted in polyethylene-covered frames at Veľká Stráž Biological Base of Forestry Research Institute as a field trial with three replications for both variants (with biostimulants and without them).

Sowing was performed on the 4th April 1992 on microplots 1.5 m^2 in size with substrate of thickness 20 cm. To control nematodes substrates were treated with 2% solution of Nematín at a dose of 20 litres per 1 m^3 before sowing and basic fertilisation was incorporated at the same time in the form of combined fertiliser Cererit at a dose of 2 kg/m^3. After a biological test with lettuce seed 800 seeds per microplot were sown in a regular design according to the template. After sowing reed mats were used to protect seeds against birds; after emergence the mats were raised as screens against the sun and they were removed before the first hand weeding of the frame in mid-June. Seedlings were not treated chemically in the growing season, the second weeding was carried out at the end of August. Two fertilisation treatments were used in the growing season: 0.2% solution of Vegaflór was applied at a dose of 10 litres per 1 m^2. The amount of artificial irrigation was determined with tensiometer located in peat substrate for all substrates in the same way.

In biostimulant variants biostimulants were applied in addition to the above treatments according to the manufacturer's instructions (JAMINEX Company). Before sowing the seed was dipped in 0.1% solution of Aminol-forte for 24 hours to stimulate germination. Sowing was performed on the 5th April 2002. After emergence and "shedding of caps" seedlings were sprayed with 0.01% solution of Fosnutren to stimulate root formation. After 25 days twice repeated sprayings of seedlings with 0.01% solution of Humiforte N 6 were carried out to stimulate shoot growth. After height increment terminated, seedlings were sprayed with 0.01% solution of Kadostim to support their lignification. Seedlings were lifted and taken for experimental measurements on the 9th October 2002.

Sampling of seedlings and measured traits

After growth termination and maturation of seedlings 10 seedlings were lifted from each substrate and replication and the following biometrical measurements were carried out:

1. Percentage sowing recovery that was defined as a difference between the number of planted seeds and that of produced seedlings
2. Root collar diameter measured to the nearest 0.05 mm
3. Stem height (shoot length) measured to the nearest 1 mm
4. Shoot dry weight (shoot weight) measured to the nearest 0.001 g
5. Number of lateral shoots
6. Main root length (root length) measured to the nearest 1 mm
7. Dry weight of root system (root weight) measured to the nearest 0.001 g
8. Number of short roots on the fifth roots with their maximum occurrence (ROOT number); they were calculated per 1 cm of root length. ROOT is taken to mean short roots maximally 0.7 cm in length that are important mainly for nutrient absorption from the substrate (Steinhübel 1984).

Arithmetical mean, standard deviation and coefficient of variation were calculated from the measurements for each biometrical variable. They were used to compare the particular treatments in the evaluation of the trial. Student's *t*-test was employed to determine statistical significance of differences in arithmetical means of compared variables.

RESULTS

Growing of spruce seedlings without biostimulants

Table 2 shows basic biometrical characteristics of spruce seedlings grown on experimental substrates.

The highest average production was recorded on P + A mix: 80.3%. Relatively good results were obtained on peat substrate (77.7%). The number of produced seedlings on the other substrates was lower (the lowest on B – 56.3% and on B + A – 63%).

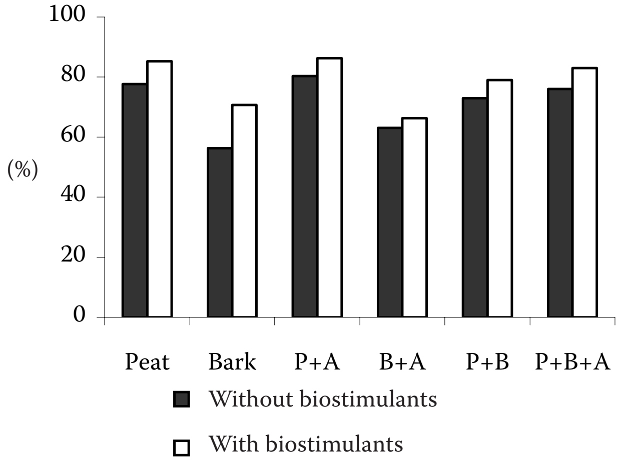

Fig. 1. Emergence of Norway spruce seedlings with the application of biostimulants and without them

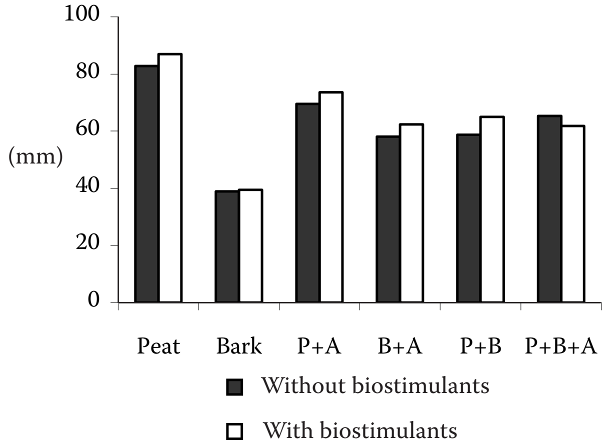

Fig. 2. Stem height in Norway spruce seedlings with the application of biostimulants and without them

The evaluation of root collar diameters indicated that seedlings of the largest diameter were produced on peat (2.04), P + B + A (1.84 mm) and P + A (1.81 mm). The smallest diameter (1.26 mm) was measured on bark substrate.

Seedlings on P + B + A and B+A formed the longest roots (253.8 and 253.3 mm, respectively). The shortest roots, on average 165.6 mm, were measured in seedlings on bark compost. As for dry weight, the highest weight was recorded in seedlings on peat (222 mg) and on P + A mix (189). The poorest root system was found out in seedlings on bark (76 mg), which was a 2.5 to3 fold difference.

The evaluation of short root formation showed a contrary influence of substrates on their development compared to all biometrical measurements. The highest ROOT per 1 cm of root length was formed by seedlings on bark compost (7.85 ROOT/cm). On the other hand, the lowest ROOT/cm was produced on peat (4.67) and on R + A mix (4.97).

The lengths (height) of seedling shoots on the particular substrates ranged from 82.8 mm on peat to 38.9 mm on bark compost. The evaluation of the number of lateral axial shoots indicated the highest average value in seedlings on peat (1.8 shoots per seedling). Seedlings on bark compost did not form any lateral axial shoot in the first year. The average numbers of shoots on the other substrates were from 1.33 (P + B + A) to 0.53 (B + A). In the evaluation of shoot dry weight the order of substrates was the same as for root dry weight while the highest values were recorded on peat (431 mg) and on P + A mix (322 mg). Seedlings on bark compost and P + B mix showed the lowest values (almost identically 127 mg).

It is to state in general that the results of all characteristics of spruce seedlings (except the ROOT fre-

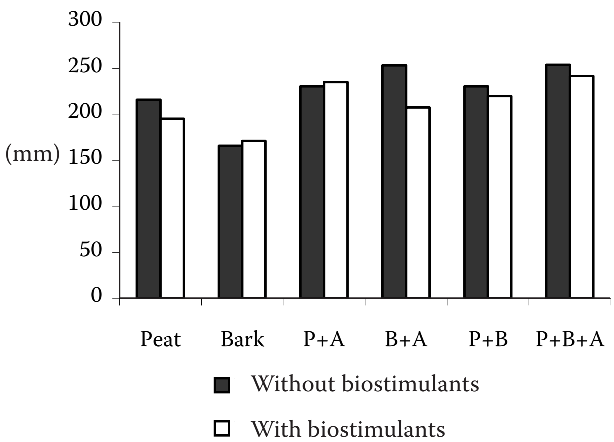

Fig. 3. Root length in Norway spruce seedlings with the application of biostimulants and without them

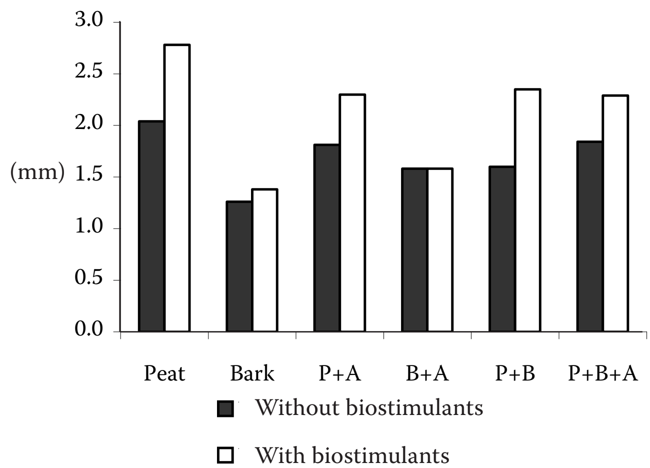

Fig. 4. Root collar diameter in Norway spruce seedlings with the application of biostimulants and without them

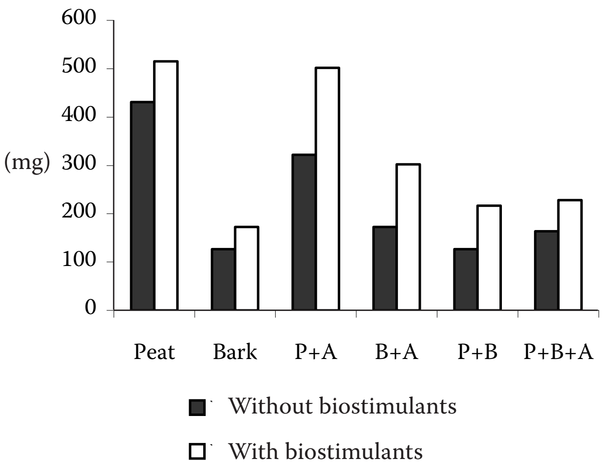

Fig. 5. Shoot dry weight in Norway spruce seedlings with the application of biostimulants and without them

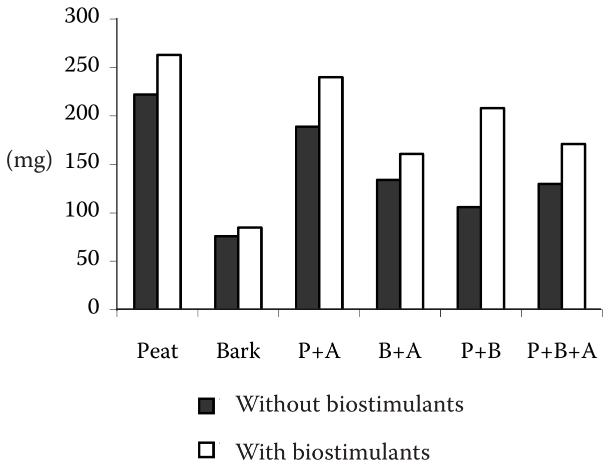

Fig. 6. Root dry weight in Norway spruce seedlings with the application of biostimulants and without them

quency) were substantially worse on substrates with addition of bark compost compared to substrates with addition of peat or agroperlite.

Evaluation of the effects of biostimulants on spruce seedling growth

Table 2 shows basic biometrical characteristics of spruce seedlings grown on the particular substrates without biostimulants and with their application.

After the application of biostimulants production on all mixes increased highly significantly. It is also documented in Fig. 1. This increase was statistically insignificant only on mixes B + A and P + B.

A highly significant increase in shoot lengths was measured in biostimulant-treated seedlings on P + B (from 58.7 mm to 64.9 mm), P + A (from 69.5 to 73.6 mm) and on B + A (from 58.1 to 62.3 mm) (Fig. 2). This increase was insignificant on bark compost and a decrease in the average height of seedlings from 65.3 mm to 61.8 mm was found out on P + B + A mix.

The evaluation of root length (Fig. 3) reflected a contrary situation when seedlings without biostimulants showed markedly better results than those treated with biostimulants except seedlings on bark compost and P + A mix where the increase was insignificant (Table 2). It can be explained by so called growth after nutrients.

Fig. 4 and Table 2 document that average diameters of root collars significantly increased on all evaluated substrates (from 10% on B to 47% on P + B) except B + A mix where the application of biostimulants did not induce any changes.

The application of biostimulants influenced the production of shoot (Fig. 5) and root (Fig. 6) biomass. The increases in shoot dry weight in per cent were as follows: 36% (B), 56% (P + A), 75% (B + A), 71% (P + B) and 39% (P + B + A). The weight increase

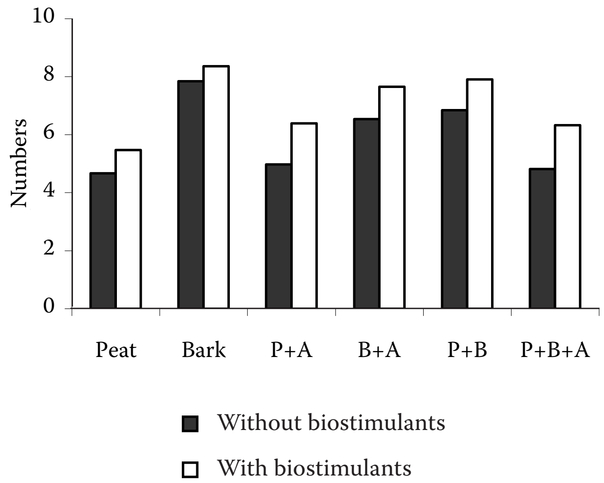

Fig. 7. Numbers of short roots/cm of root length in Norway spruce seedlings with the application of biostimulants and without them

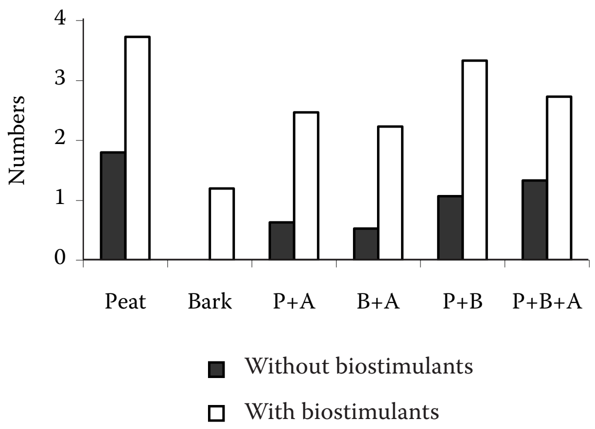

Fig. 8. Number of lateral shoots in Norway spruce seedlings with the application of biostimulants and without them

on P was statistically insignificant. Similarly like in the comparison of root dry weight, higher values in seedlings treated with biostimulants were calculated for all substrates (from 19% on peat to 96% on P + B mix). The increase was statistically insignificant only in seedlings on bark substrate.

The influence of biostimulants on an increase in ROOT number and in the number of lateral shoots on the seedling axis was still more marked (Fig. 7). Statistically highly significant differences were determined between seedlings on all six tested substrates.

The formation of lateral shoots was influenced by biostimulants positively (Fig. 8) when statistically highly significant increases in the number of lateral shoots were also determined on all substrate mixes.

DISCUSSION

From the aspect of the influence of particular substrates on quantitative and qualitative characteristics of spruce seedlings, the use of peat substrates brought the best results as expected. Relatively good results were also obtained after agroperlite was added at a volume ratio 1:1. Its addition to substrate mixes was recommended by Lipták and Saniga (1982), Lipták et al. (1990), Slávik (1990).

The analysis of the heights of seedlings grown on particular substrates indicated that seedlings produced on substrate from dry upland peat and its mixes with perlite (1:1) exceeded by their heights significantly or highly significantly seedlings grown on the other substrates. These substrate mixes maintain their physical properties for a longer time, even longer than the peat itself (Soukup, Matouš 1979; Bedrna 1989). Similarly, the best results were obtained for the production and shoot and root weights of seedlings grown on peat and its mix with agroperlite P + A (1:1). Our findings were fully consistent with the results of cited authors.

In addition, our unsatisfactory results of direct growing of seedlings on pure substrates made of composted spruce bark correspond with conclusions of Bluďovský (1975), Fencl (1977), Skoupý (1977), Mauer (1988), etc. These authors did not recommend to use pure bark for seedling production.

The use of bark-agroperlite mixes at a ratio 1:1, as also recommended by Mauer (1988), seems more suitable. In our experiments, most biometrical characteristics showed higher values on B + A substrates than on pure bark compost.

Substrate mixes made of peat and bark compost at a volume ratio 1:1 are considered by many authors as suitable substrates for the production of seedlings of forest tree species. Among others, it was confirmed by Ferda (1976), Chalupa (1980) and Demko and Šmelková (1994), and also by our experiments where the results on peat + bark substrates were relatively good.

One of the morphological characteristics that have not been evaluated very frequently until now is the number of short roots (ROOT). Steinhübel (1982, 1984) called these roots shortened root branches (SRB). He was convinced that some forest tree species that did not have any root hairs or a very low number of root hairs compensated the deficient size of the active surface by increased formation of short roots. It was observed that the increased ROOT frequency compensated the lack of thin roots with active surface while the frequency of short roots decreased under rich formation of thin roots (Steinhübel, Lipták 1985). If the mycorrhiza is insufficient, the former phenomenon occurs.

In our experiments roots of seedlings grown on the poorest substrates also formed the highest amount of ROOT.

In general, the application of biostimulants had positive effects on all examined quantitative and qualitative traits on most substrates, especially on the formation of lateral shoots, diameter and height growth. They also positively influenced the formation of short roots – ROOT.

As we used biostimulants of a new firm (JAMINEX) in our experiment and as its products were not tested by many authors until then, we could compare our results with conclusions of a limited number of authors. The comparison of our experiments with their results (Chlepko et al. 1995) indicated that they also recorded positive effects of biostimulants on seedling germination and growth in their tests.

In our experiments during tests of spruce seedlings on peat substrate we recorded higher values of all examined traits after biostimulant applications compared to internal materials of JAMINEX Company. In our experiments the increase in root collar diameters was highly significant while in JAMINEX material the difference was reported as insignificant.

CONCLUSION

The percentage proportion of the number of spruce seedlings in the number of planted seeds was about 60–86%, which is an adequate result for a forest operation. A higher number of seedlings was produced on mixes containing peat and also agroperlite compared to mixes with composted spruce bark. The pre-sowing dipping of seeds in the biopreparation

Aminol Forte also positively influenced the number of produced Norway spruce seedlings.

From the practical aspect, Norway spruce seedlings grown on most substrate mixes (except composted bark substrates) complied with the length criteria for transplanting.

The evaluation of all quantitative traits showed that they were positively influenced by the presence of peat in substrate mixes; on the other hand, an increase in the proportion of bark compost led to a decrease in all quantitative traits (length and weight ones).

The application of biostimulants increased the frequency of short roots and the number of lateral shoots in tested seedlings.

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Pestovanie semenáčikov smreka obyčajného (*Picea abies* [L.] Karst.) na zmiešaných substrátoch s využitím stimulátorov rastu

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ABSTRAKT: V práci sa hodnotí rast semenáčikov smreka obyčajného (*Picea abies* [L.] Karst.) na rašelinových a kôrových substrátoch, na ich vzájomných zmesiach i na ich zmesiach s agroperlitom. Sledujú sa nielen základné kvantitatívne parametre (hrúbky a výšky semenáčikov), ale aj množstvo vypestovaných semenáčikov na jednotke plochy, dĺžky hlavných koreňov, počet vetiev na osi a hmotnosti sušiny nadzemnej i podzemnej časti. Okrem zisťovania vplyvu substrátu na sledované biometrické charakteristiky semenáčikov pri bežnom prevádzkovom hnojení sa ako druhá varianta pokusov založil pokus, kde sa overoval vplyv biostimulátorov, ktoré na testovanie dodala firma JAMINEX. Pokus bol založený podľa bežných prevádzkovo-pestovných technológií v trojnásobnom opakovaní. Je možné konštatovať, že aj v našich pokusoch sa ako najvhodnejší substrát na pestovanie semenáčikov smreka ukázala rašelina. Kladný vplyv biostimulátorov sa prejavil veľmi významne na takmer všetkých testovaných substrátových zmesiach.

Kľúčové slová: semenáčiky smreka; substráty a ich zmesi; ošetrovanie biostimulátormi

Narastajúce požiadavky na množstvo a kvalitu sadbového materiálu kladú stále vyššie nároky na škôlkarsku výrobu a s tým spojené škôlkárske technológie. Medzi škôlkárske technológie, ktoré môžeme z pohľadu efektívnosti škôlkárskej výroby považovať za optimálne (šetrenie semena, skracovanie výrobnej doby, zvyšovanie bezpečnosti produkcie), patrí pestovanie semenáčikov na substrátoch. Je všeobecne známe, že najpoužívanejším a najefektívnejším substrátom v škôlkárskej výrobe je a ostáva rašelina.

Zásoby rašeliny sú však, najmä na Slovensku, značne obmedzené. Hľadajú sa preto iné vhodné materiály, ktoré by ju mohli nahradiť, resp. aspoň znížiť jej spotrebu. Určitým riešením sa ukazuje využitie substrátov vyrobených na báze drevných odpadov a tzv. kombinovaných substrátov z organického a anorganického materiálu.

Pri pestovaní sadbového materiálu vznikajú pomerne vysoké straty. Jednou z možností zníženia strát pri produkcii sadbového materiálu a zároveň zlepšenia kvantitatívno-kvalitatívnych parametrov vypestovaných semenáčikov môže byť využitie biostimulátorov – látok podporujúcich rast rastlín.

Cieľom práce bolo posúdiť vplyv jednotlivých substrátov a biostimulátorov na produkciu a kvalitu vypestovaných semenáčikov smreka.

Pokus bol založený vo výskumnom objekte LVÚ Biologická základňa Veľká Stráž, asi 3 km severozápadne od Zvolena. Výskumná plocha sa nachádza v geografickom celku Zvolenská kotlina v nadmorskej výške 320 m a je situovaná v teréne so sklonom asi do 5 %. Priemerné ročné teploty sa tu pohybujú medzi 7–8 °C, vo vegetačnom období medzi l3–l4 °C. Priemerný počet letných dní je 40, počet mrazových dní do roka je 50. Ročný úhrn zrážok je 650–700 mm, z čoho na vegetačné obdobie pripadá 350–400 mm.

Pokusy sa uskutočnili v polyetylénovom kryte (PEK) na Biologickej základni LVÚ Veľká Stráž formou poľného pokusu s trojnásobným opakovaním pre obidva varianty (s biostimulátormi a bez nich).

Výsev sa vykonal 4. 4. 1992 na plôškach 1,5 m^2 so substrátmi navrstvenými do hrúbky 20 cm. Pred výsevom boli substráty ošetrené proti háďatkám 2% roztokom Nematínu v dávke 20 l na 1 m^3 a zároveň bolo do nich zapracované základné hnojenie prostredníctvom kombinovaného hnojiva Cererit v dávke 2 kg/m^3. Po vykonaní biologického testu semenom šalátu sme vysiali pravidelne podľa šablóny semená v počte 800 semien na jednu plôšku. Po vysiatí sme semená chránili proti vtákom rákosovými rohožami, ktoré boli po vyklíčení zdvihnuté ako ochrana proti slnku a úplne odstránené pred prvým ručným pletím záhona v polovici júna. V priebehu vegetačnej doby semenáčiky neboli chemicky ošetrované. Druhé pletie bolo vykonané koncom augusta. Hnojenie v priebehu vegetačnej doby sa uskutočnilo dvakrát, a to 0.2% roztokom Vegaflóru v dávke 10 l na 1 m^2. Množstvo umelej závlahy sa stanovilo pomocou tenziometra umiestneného v rašelinovom substráte pre všetky substráty rovnako.

Pri variantách s biostimulátormi boli navyše aplikované biostimulátory podľa metodiky výrobcu (firma JAMINEX). Pred výsevom sa pre podporu klíčenia namáčalo osivo 24 hodín v 0.1% roztoku prípravku Aminol-forte. Výsev bol vykonaný 5. 4. 2002. Po vyklíčení a „zhodení čiapočiek“ sme semenáčiky postrekovali 0.01% roztokom Fosnutrenu na podporu tvorby koreňov. Po 25 dňoch sme dvakrát opakovane postrekovali semenáčiky 0.01% roztokom Humiforte N 6 pre podporu rastu nadzemnej časti. Po ukončení výškového prírastku sme semenáčiky postriekali 0.01% roztokom Kadostimu pre podporu ich zdrevnatenia. Semenáčiky boli vyzdvihnuté a vzorky na pokusné merania odobraté 9. 10. 2002.

Po ukončení rastu a vyzretí semenáčikov sa z každého substrátu a opakovania vyzdvihlo po 10 semenáčikov, na ktorých sa uskutočnili nasledovné biometrické merania:

1. Percentuálna výťažnosť výsevu, ktorá sa určila na základe rozdielu počtu vysiatych semien a vypestovaných semenáčikov
2. Hrúbka koreňového krčka s presnosťou 0,05 mm
3. Výška stonky (dĺžka NZ) s presnosťou na 1 mm
4. Hmotnosť sušiny nadzemnej časti (hmotnosť NZ) s presnosťou na 0,001 g
5. Počet bočných výhonkov
6. Dĺžka hlavného koreňa (dĺžka PZ) s presnosťou na 1 mm
7. Hmotnosť sušiny koreňovej sústavy (hmotnosť PZ) s presnosťou na 0,001 g.
8. Počet koreňov obmedzeného rastu na piatych koreňoch s ich maximálnym výskytom (počet KOR); prepočítali sme ich na 1 cm dĺžky koreňa.

Z nameraných hodnôt sme pre každú biometrickú veličinu vypočítali aritmetický priemer, smerodajnú odchýlku a variačný koeficient. Tie sme použili pri vyhodnocovaní pokusu na porovnávanie jednotlivých variantov. Štatistickú významnosť rozdielov aritmetických priemerov porovnávaných veličín sme testovali pomocou Studentovho t-testu.

Percentuálny podiel počtu semenáčikov smreka z počtu vysiatych semien sa pohyboval od 60 do 86 %, čo možno aj pre prevádzkové podmienky považovať za primeraný výsledok. Viac semenáčikov bolo vypestovaných na zmesiach s podielom rašeliny a tiež agroperlitu oproti zmesiam, v ktorých bola zastúpená kompostovaná smreková kôra. Kladný vplyv na množstvo vyrastených semenáčikov smreka malo aj predosevné máčanie semien v bioprípravku Aminol-forte.

Z praktického hľadiska je nutné povedať, že semenáčiky smreka obyčajného, vypestované na väčšine sledovaných substrátových zmesí (s výnimkou kompostovaných kôrových substrátov), spĺňali dĺžkové kritériá na škôlkovanie.

Pri hodnotení všetkých kvantitatívnych parametrov možno konštatovať, že na ne mala kladný vplyv prítomnosť rašeliny v substrátových zmesiach, naopak zvyšovaním sa podielu kôrového kompostu všetky kvantitatívne parametre (dĺžkové i hmotnostné) klesali.

Naopak aplikovaním biostimulátorov stúpala frekvencia koreňov obmedzeného rastu a narastal počet bočných vetiev testovaných semenáčikov.

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