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PHYSIOLOGICAL ASPECTS IN PROPAGATION OF SMOKE TREE (*Cotinus coggygria* Scop. 'Royal purple') BY STEM CUTTINGS

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Abstract. Biostimulators are preparations intended to improve plant growth and development, especially under stressful conditions. The aim of the study was to evaluate the effect of two biostimulators: AlgaminoPlant (0.2%) and Route (0.1%) on rooting of *Cotinus coggygria* Scop. 'Royal Purple' and their influence on biochemical changes, respiration efficiency and photosynthetic rate during this process. Cuttings were sprayed with water solution of biostimulators once, twice or three times during the rooting period at week intervals. The effectiveness of biostimulators was compared with the formulations traditionally used in the nursery production, i.e. with a rooting powder Rhizopon AA containing a synthetic auxin IBA (2%) or a water solution of IBA (200 $mg \cdot dm^{-3}$) applied on leaves. Triple treatments of microcuttings with AlgaminoPlant and a single one with Route significantly increased a rooting degree relative to the untreated control. The highest photosynthesis rate was observed in cuttings sprayed once with AlgaminoPlant and twice with Route. Respiration efficiency was the highest in cuttings treated once and thrice with AlgaminoPlant. The significant increases in chlorophyll ($a + b$), total soluble and reducing sugars contents were observed in cuttings treated with both biostimulators in comparison to the control. The results suggest that biostimulators applied on cuttings may cause biochemical and physiological changes which increase the stem ability to regenerate roots therefore their application should be considered in nursery practice.

Key words: rhizogenesis, auxin, photosynthesis, respiration, carbohydrates, proteins

INTRODUCTION

Biostimulators are used in horticulture in order to obtain the highest possible yield and best quality crops, especially in conditions which are not optimal for growth and

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development of plants [Gawrońska et al. 2008, Przybysz et al. 2010]. The consequence of limiting the commercial use of the auxin formulations (containing synthetically derived plant hormones and other compounds such as fungicides) was the start of the research on use of biostimulators as rhizogenesis stimulants due to their high efficiency in root growth stimulation and acclimatization of plants to difficult growing conditions [Ludwig-Muller 2000, Khan et al. 2009, Pacholczak et al. 2012]. Biostimulators improve some processes within cells, thus increasing plant vitality and enhancing growth and vigor, important for potential consumers [Gawrońska et al. 2008, Matyjaszczyk et al. 2008]. Their action may include intensification of the synthesis and activity of the natural hormones, facilitation of absorption of nutrients or stimulation of root development [Jankowski and Dubis 2008, Pruszyński 2008, Kumar and Sahoo 2011]. There is no official definition for biostimulators because of the diversity of their origin, their active substances, production technology and mode of action. In many cases it is the reason for diverging opinions during classification and selection rules of their legislation. They are described as single- or multicompound preparations based on extracts of natural substances of plant or animal origin, containing in their composition amino acids and polypeptides of low molecular weight, vitamins, enzymes and hormones (auxin, cytokinin, gibberellin), sugars, antioxidants as well as components stimulating enzymatic activity in plant tissues [Basak 2008]. Biostimulators such as AlgaminoPlant [Matysiak et al. 2010] or Route [Horne and Leitch 2006] have been reported to positively affect nursery plant production. Results of tests of their efficacy in propagation of ornamental woody plants appear promising [Pacholczak et al. 2012, 2013b].

AlgaminoPlant (Varichem, Poland) is a liquid preparation produced on the base of a seaweed extract (18%) from *Sargassum*, *Laminaria*, *Ascophyllum*, and *Fuscus*. It contains phytohormones whose gibberellin-like activity expressed in equivalents of gibberellic acid is equal to 0.005% GA_3, while the cytokinin activity is equal to 0.0005% BA, and the auxin like activity corresponds to 0.003% IAA. It is supplemented by potassium salts of amino acids at 10% [Matysiak et al. 2010].

Route (Dalgety, Poland) is a formulation of zinc ammonium acetate (ZAA) composed of acetic acid, water, ammonium, and zinc oxide. Route increases the endogenous auxin content and reinforces (about 18%) cell walls, thus reducing their porosity and indirectly decreasing nutrient loses from cells. ZAA action in a process of rhizogenesis is associated with stimulation of endogenous auxins' biosynthesis, what changes the auxin to cytokinin ratio. This in turn results in a more abundant production of auxillary roots [Horne and Leitch 2006].

Gas exchange of plants involves respiration, photosynthesis and transpiration – processes affected by biostimulators and indicators of plants vigor [Gawrońska et al. 2008, Przybysz et al. 2008]. Since biostimulators had been shown to affect the photosynthesis and respiration rate of plants [Przybysz et al. 2008], an attempt was made to detect a relationship between some parameters of gas exchange in cuttings, as influenced by treatments, and the subsequent rhizogenesis [Pacholczak and Pietkiewicz 2014a, b].

A conventional propagation of *C. coggygria* Scop. 'Royal Purple' may be problematic [Pacholczak et al. 2013a]. In order to intensify it the suitability of Route and AlgaminoPlant for the propagation of smoke tree by stem cuttings has been evaluated and their effects on several biochemical and physiological processes occurring during rhizogenesis determined.

MATERIALS AND METHODS

The experiments were carried out in 2012 and 2013 in a commercial nursery of M.M. Kryt in Wola Prażmowska, on smoke tree (*C. coggygria* Scop. 'Royal Purple'). Semi lignified two nodal stem cuttings were prepared from shoots harvested from stock plants free from pathogens and diseases. Cuttings were rooted in styrofoam boxes. They were inserted to the depth of 2 cm into a mixture of peat, perlite and sand (2:1:1), pH 5.0. The mixture was thoroughly wetted and pressed, and covered with 0.5 cm layer of coarse sand. Two biostimulators were used, in aqueous solutions: AlgaminoPlant (0.2%) and Route (0.1%). Cuttings were sprayed with either solution once, twice or three times during the rooting period at week intervals. The effects of the two preparations were compared to those of the synthetic auxin (β-indolilobutyric acid, IBA). IBA was applied either directly to the bases of cuttings in the form of the commercially available rooting powder Rhizopon AA (2% IBA), or by spraying cuttings with aqueous solution of 200 $mg \cdot dm^{-3}$ IBA. Control cuttings were sprayed with distilled water. The experiment began on July 3 and ended on August 28, 2012 and on July 2 and ended on August 27, 2013 and consisted of nine treatments (tab. 1), each in three replications, each replication containing 20 cuttings.

Table 1. A list of treatments in the experiment

No. of treatment	Methods of cuttings treatment
1	Control '0' 1 spraying with distilled water (H_2O)
2	Rhizopon AA (2% IBA) powder
3	1 spraying with IBA 200 $mg \cdot dm^{-3}$
4	1 spraying with AlgaminoPlant 0.2%
5	2 sprayings with AlgaminoPlant 0.2%
6	3 sprayings with AlgaminoPlant 0.2%
7	1 spraying with Route 0.1%
8	2 sprayings with Route 0.1%
9	3 sprayings with Route 0.1%

Water and the solutions tested were applied with a hand pressure sprayer (volume $1 \cdot dm^{-3}$) on the start date of the experiment (July 3, 2012 and July 2, 2013), and repeated twice at one week intervals. Rooting took place in plastic tunnels equipped with automatic watering and mist systems as well as with shading devices. During the first two weeks, the cuttings were protected against sun with an opaque foil and a shading cloth. Every two weeks, cuttings were sprayed against *Botrytis* with 0.2% Rovral or Bravo.

Percentages of rooted cuttings and the degree of rooting were determined 8 weeks after the start of the experiment. The degree of rooting was evaluated on a 5-point scale rating the development of the root ball (tab. 2, phot. 1) provided by Pacholczak and Szydło [2008]. The scores for the degree of rooting represent means of three independent observations by trained personnel. Percent of rooted cuttings was also calculated – only the cuttings with root system within the scale range of 2–5 were regarded as rooted and counted.

Table 2. Evaluation scale of the root development

Characteristic of the degree of rooting	Score
Cutting without visible roots	1
A few (1–3) short roots	2
4–5 roots, some of them branched, no root ball formed	3
Medium sized root system composed of 6–10 branched roots forming a root ball	4
Well developed, branched root system forming a root ball (over 10 roots)	5

Phot. 1. Characteristic of the degree of rooting

On July 17, 2012 and July 16, 2013 the following measurements of the gas exchange parameters were done: R_d – respiration rate ($\mu\cdot$mol $CO_2\cdot m^{-2}\cdot s^{-1}$) and P_n – net photosynthetic rate ($\mu\cdot$mol $CO_2\cdot m^{-2}\cdot s^{-1}$). The parameters of gas exchange were measured by the CIRAS-2 gas analyzer (PP System Inc., Amesbury, MA, USA). The measurements were done in triplicate, at noon, under natural irradiance of 1000–1400 µmol PAR$\cdot m^{-2}\cdot s^{-1}$ at 25°C, RH 50–60% and CO_2 concentration 300–350 µmol$\cdot$mol^{-1} air. Conditions under tunnel where cuttings for measurements were grown and sampled were: 30–39°C, RH 90–100%. The respiration rate was determined after shading the measurement chamber and photosynthesis extinction. Measured with an infrared gas analyzer, negative photosynthetic rate is equal to the respiration rate.

For biochemical analyses, leaves from 20 cuttings per treatment were collected three weeks after the beginning of the experiment, from treated and untreated cuttings. They were finely chopped, mixed and 0.5 g samples were used for the measurements of dry matter and contents of chlorophyll (*a* + *b*), reducing and total sugars, free amino acids and soluble proteins. Triplicate extracts were prepared for each analysis and three measurements were done for each extract producing nine readings for each data point.

For the dry matter content, 1 g samples were dried at 105°C to constant weight [Strzelecka et al. 1982]. Total chlorophyll content (chlorophyll *a* + *b*) was analyzed according to Lichtenthaler and Wellburn [1983]. Reducing sugars were determined by the colorimetric method of Somogyi in the Nelson's modification [Nelson 1944], and total soluble sugars were determined according to Dubois et al. [1956]. Free amino acids were measured by the method of Rosen et al. [1957] and soluble proteins according to Lowry et al. [1951].

Statistical analyses. To compare the means, percentages of rooted cuttings were transformed according to Bliss [Wójcik and Laudański 1989], while the degree of rooting by root transformation: $y = x^2 + (x + 1)^2$, subjected to ANOVA 1 and tested by the Duncan's test at $\alpha = 0.05$. Results of the biochemical analyses and gas exchange analyses were subjected to the 2-factorial ANOVA and the means were compared by the Duncan's test at $\alpha = 0.05$.

RESULTS

The two factorial analysis of variance showed the effect of both, the treatments and the season on parameters tested in cuttings of *C. coggygria* Scop. 'Royal Purple'. Only for the carbohydrate contents the effect of season was insignificant.

Degree and percent of rooting. A degree of rooting in control cuttings was by 40% lower in 2013 than in 2012 when none of the preparations affected is as compared to control untreated cuttings. In 2013 the degree of rooting in cuttings treated with Rhizopon AA was twice as high as in the control. Also the foliar application of the water IBA solution increased the degree of rooting by 40% as compared with untreated cuttings. Similar effect was obtained after three-fold application of AlgaminoPlant and a single spraying with Route (tab. 3).

The percentage of rooted cuttings in 2013 was almost by half lower than in 2012. In 2012 only the use of Rhizopon AA resulted in an increase (18%) of rooted cuttings relative to the control treatment. Next year this increase was *ca* 48% being comparable to the result of the foliar application of the IBA solution. Good results were also obtained after Route application (tab. 3).

Photosynthesis rate. All the treatments increased the mean value of photosynthesis (P_n) and the two-fold application of Route was especially effective in this regard: in 2012 it more than doubled the photosynthetic rate relative to the control, similarly as did the Rhizopon AA application next year 2013 (tab. 4).

Table 3. Effect of Rhizopon AA (Rh.AA), IBA, AlgaminoPlant and Route on rooting degree and rooting percentage of *Cotinus coggygria* 'Royal Purple' cuttings

Treatment	Year	Contr.	Rh. AA	IBA	AlgaminoPlant			Route			Means (year)
					× 1	× 2	× 3	× 1	× 2	× 3	
Rooting degree	2012	2.6 bc*	2.5 bc	2.9 cd	2.5 bc	2.4 bc	2.6 bc	2.8 cd	2.7 cd	2.8 cd	2.7 b
	2013	1.6 a	3.0 d	2.6 bc	1.7 a	2.6 bc	2.7 cd	2.7 cd	2.2 b	1.5 a	2.3 a
	means (treatment)	2.1 a	2.75 c	2.75 c	2.1 a	2.5 b	2.65 bc	2.75 c	2.45 b	2.15 a	–
Rooting percentage	2012	73.3 de	86.7 f	76.7 ef	73.3 de	66.7 cd	61.0 cd	63.3 cd	70.0 de	61.0 cd	70.0 b
	2013	41.7 ab	61.7 cd	61.0 cd	40.0 a	43.3 ab	45.0 ab	45.0 ab	55.0 bc	38.3 a	47.8 a
	means (treatment)	57.5ab	74.2d	68.9cd	56.7 ab	55.0ab	53.0 a	54.2ab	62.5 bc	49.7 a	–

* – means followed by the same letter do not differ significantly at α = 0.05

Table 4. Effect of Rhizopon AA (Rh.AA), IBA, AlgaminoPlant and Route on photosynthesis rate ($\mu M\ CO_2 \cdot m^{-2} \cdot s^{-1}$) and respiration efficiency ($\mu M\ CO_2 \cdot kg^{-1} \cdot s^{-1}$) of *Cotinus coggygria* 'Royal Purple' cuttings

Treatment	Year	Contr.	Rh. AA	IBA	AlgaminoPlant			Route			Means (year)
					× 1	× 2	× 3	× 1	× 2	× 3	
Photosynthesis rate	2012	1.2 a*	2.5 ab	2.6 ab	4.5 fg	3.8 cde	3.9 cde	2.5 ab	5.5 i	4.7 gh	3.5 a
	2013	2.6 ab	5.4 hi	3.9 cde	4.0 efg	4.3 efg	3.7 cd	3.3 bc	4.7 gh	2.3 ab	3.8 b
	means (treatment)	1.9 a	3.9 cd	3.2 bc	4.2 de	4.1 cd	3.8 bcd	2.9 b	5.1 e	3.5 bcd	–
Respiration efficiency	2012	1.0 bcd	1.0 bcd	1.0 bcd	1.6 f	1.6 f	1.7 f	1.0 bcd	1.1 de	1.6 f	1.3 b
	2013	0.8 ab	0.7 a	0.8 ab	1.3 e	0.9 bcd	0.9 bcd	1.1 de	1.1 de	0.9 bcd	0.9 a
	means (treatment)	0.9 a	0.85 a	0.9 a	1.45 d	1.25 bc	1.3cd	1.1 b	1.1b	1.25bc	–

* – means followed by the same letter do not differ significantly at α = 0.05

Respiration efficiency. In 2012 the intensity of gas exchange was higher than in 2013. The lowest respiration rates were recorded in cuttings treated with synthetic auxins. In 2012 AlgaminoPlant at lower doses and Route in the highest one (three-fold application) increased respiration rate by 60% as compared to the control treatment. In 2013 both biostimulators affected the respiration to a lesser degree: the 30% icrease was found after the single spraying with AlgaminoPlant (tab. 4).

Total chlorophyll content (*a* + *b*). In 2012 the cholorophyll content remained on a similar level in cuttings from all the treatments while in 2013 the application of rooting stimulants increased pigment amounts by 50% relative to the control (tab. 5).

Total and reducing sugar content. Total sugar content and reducing sugar content in cuttings did not differ significantly between the years. Treatments with auxin and both biostimulators increased the carbohydrate levels by *ca* 15% relative to the control. The rooting stimulatns – regardless of their origin – increased by 30% the sugar content as compared to the control treatment (tab. 5).

Table 5. Effect of IBA, AlgaminoPlant and Route on total chlorophyll, total sugar and reducing sugar content ($mg \cdot g^{-1}$ d.m.), free amino acids (μM of leucine $\cdot g^{-1}$ d.m.) and soluble proteins content ($mg \cdot g^{-1}$ d.m.) in cuttings of *Cotinus coggygria* 'Royal Purple'

Treatment / content	Year	Contr.	IBA	Algamino-Plant	Route	Means (year)
Chlorophyll	2012	5.3 a*	5.3 a	5.6 a	5.4 a	5.4 a
	2013	4.8 a	5.7 a	7.5 b	6.9 b	6.3 b
	means (treatment)	5.05 a	5.5 a	6.6 b	6.15 b	–
Total sugar	2012	173.5 a	193.4 b	194.9 b	198.6 b	190.1 a
	2013	177.8 a	206.6 b	211.8 b	201.8 b	199.5 a
	means (treatment)	175.7 a	200.0 b	203.4 b	200.2 b	–
Reducing sugar	2012	89.1 a	101.2 a	123.4 b	121.7 b	108.8 a
	2013	81.7 a	108.3 b	110.9 b	105.9 b	101.7 a
	means (treatment)	85.4 a	104.8 b	117.2 b	113.8 b	–
Free amino acids	2012	221.8 a	243.9 a	280.5 c	250.4 b	249.2 a
	2013	245.4 b	307.2 c	305.8 c	290.8 c	287.3 b
	means (treatment)	233.6 a	275.6 b	293.2 b	270.6 b	–
Soluble proteins	2012	111.9 c	139.2 cd	159.6 d	154.6 d	141.3 b
	2013	52.6 a	82.4 b	89.4 b	94.6 b	79.8 a
	means (treatment)	82.3 b	110.8 b	124.5 b	124.6 b	–

* – means followed by the same letter do not differ significantly at $\alpha = 0.05$

Free amino acid content. The free amino acid content in control cuttings was by 10% higher in 2013 than in 2012. In 2012 the auxin and both biostimulators increased the free amino acid level by *ca* 10% relative to the control. Next year this increase was 20% (tab. 5).

Soluble proteins content. Content of soluble proteins in cuttings was more than twice as high in 2012 than in 2013. In 2012 the application of biostimulators resulted in 40% increase in soluble proteins while the spraying with IBA increased proteins by 25%. In 2013 the auxin application increased the soluble proteins by 60% relative to the control, while the use of AlgaminoPlant and Route by 70 and 80%, respectively (tab. 5).

DISSCUSION

The formation of the root ball by a stem cutting is a process depending on many internal and external factors [Spethmann 2001]. Auxin-based preparations have been routinely used to enhance rhizogenesis with β-indolilobutyric acid (IBA) being the most effective. Pacholczak et al. [2013b] in the trials on *Physocarpus opulifolius* 'Dart's Gold' and 'Red Baron' obtained the best rooting results with the foliar applications of the IBA water solution (200 $mg \cdot dm^{-3}$). Pacholczak and Szydło [2008] reported positive effects of Rhizopon AA (containing IBA) also in ninebark. In this study, both methods of IBA application (rooting powder Rhizopon AA and foliar application of the IBA water solution) stimulated rhizogenesis by increasing the percentage and the degree of rooting, particularly in 2013.

Plants treated with biostimulators exhibit better adaptability to stressful conditions such as detaching from the stock plants [Schmidt et al. 2003]. Mugnai et al [2008] conducted a study aiming at determining the effect of bioactive substances from marine algae on rooting of cuttings in *Vitis vinifera*. Results showed improvement in structure, size and health of the roots of the vine cuttings as well as enhanced growth of young shoots. Also Pacholczak et al [2013b] in their study obtained good results with *Physocarpus opulifolius* 'Dart's Gold' and 'Red Baron' treated with AlgaminoPlant, but the effects were variable depending on the number of spray treatments. Similar results were obtained after trials on dogwood (*Cornus alba* 'Aurea' and 'Elegantissima') [Pacholczak et al. 2012].

Route preparation is based on zinc ammonium acetate (ZAA) which affects the auxin biosynthesis intensity, thus contributing to improvement of the root system development [Cattanach 1992, Pacholczak and Szydło 2008]. Pacholczak and Szydło [2008] also showed that its foliar application can improve the percentage and the degree of rooting of *P. opulifolius* cuttings. In this work both preparations enchanced degree of rooting but only in 2013 when the use of the higher doses of AlgaminoPlant and a single application of Route were effective.

The efficiency of the photosynthetic apparatus in cuttings remains low during rooting until the first roots appear. Therefore little energetic substrates are available in the early stages of rhizogenesis. They are indispensable for respiration which provides energy for rhizogenesis, a process demanding a high energy input [Couvillon 1988, Spethmann 2001]. In this study, both preparations increased the activity of the photosynthetic system, and the respiration efficiency except Route applications in 2012. Positive effects of biostimulators on the photosynthetic rate were reported in *Arabidopsis thaliana* [Przybysz et al. 2010, Borowski and Blamowski 2009], *Cornus alba* [Pacholczak and Pietkiewicz 2014b] and *Physocarpus opulifolius* [Pacholczak and

Pietkiewicz 2014a] where the intensified photosynthesis was observed in cuttings treated with the higher dosages of biostimulators.

The efficiency of the photosynthetic apparatus depends on the chlorophyll contents [Couvillon 1988]. Both biostimulators tested enhanced chlorophyll synthesis, though only in 2013. Jacygrad and Pacholczak [2010] reported an increase in green pigment contents in ninebark cuttings treated with the biostimulator Amino Total which – similarly to AlgaminoPlant used here – contains a mixture of amino acids. Jothinayagi and Anbazhagan [2009] observed that in *Abelmoschus esculentus* the chlorophyll content increased by 20% after applications of low doses of seaweed extracts while their high doses limited pigment synthesis. According to Khan et al. [2009] both soil and foliar applications of an extract from *Ascophylum nodosum* in a low concentration increased chlorophyll content in tomato leaves. Matysiak et al. [2011] recorded the 40% increase in green pigment content in plants of *Zea mays* after a double foliar application of AlgaminoPlant. Also Pacholczak et al. [2012] observed an elevated chlorophyll level in dogwood cuttings treated with AlgaminoPlant. However, Venkatamaran Kumar and Mohan [1997] reported a negative effect of seaweeds on chlorophyll content in *Vigna mungo* var. *mungo.* An increase in the chlorophyll content was also observed after zinc application on plants [Nahed et al. 2007], however, a fall in pigment level occurred after a treatment with a high zinc dose. Reports on the positive effects of zinc on chlorophyll synthesis come also from the trials on cypress (*Cupressus sempervirens*) [Farahat et al. 2007] and pea (*Pisum sativum*) [Massoud et al. 2005].

Carbohydrate accumulation in plant tissues is crucial for successful propagation by cuttings as rhizogenesis demands a high energy input, especially in the first stages of root initiation. Sugars are substrates for respiration that provide energy necessary for organ differentiation [Couvillon 1988, Costa et al. 2007]. According to Sivasankari et al. [2006] the levels of reducing and total soluble sugars increase in plants of *Vigna sinensis* after seaweed extract applications. Rathore et al. [2009] reported an increase in the carbohydrate contents in plants of *Glycine max* treated with a biostimulator based on an extract from *Kappaphycus alvarezii.* However, Jacygrad and Pacholczak [2010] observed a drop in a sugar content in cuttings of two ninebark cultivars treated with biostimulator Amino Total although this drop did not affect the rooting ability. In dogwood, the carbohydrate levels in cuttings increased after a treatment with AlgaminoPlant [Pacholczak et al. 2012]. Zinc applications also resulted in an increase in sugar content in *Ocimum basilicum* [Bedour et al. 1994] and radish [Nabila et al. 2003] although no such changes were observed in *Salvia farinacea* [Nahed et al. 2007]. In the present work, both biostimulators increased the amounts of reducing sugars and total soluble sugars in both seasons.

Amino acids are used for protein synthesis and their binding into macromolecules is a process requiring a high energy input. Plants are able to synthesize all amino acids needed for peptide and protein synthesis but supplying them with an mixture of exogenous amino acids may save energy and improve growth of cuttings, especially in the critical developmental stages when large amounts of proteins or their precursors are needed [Bojarczuk 1997]. A positive correlation between an elevated level of free amino acids and rhizogenesis in six species (*Trifolium repens*, *Lolium perenne*, *Zea mays*, *Brassica napus*, *Lycopersicon esculentum*, *Medicago sativa*) was reported by Lessufleur et al. [2007]. In ninebark, the amino acid content increased during rooting [Jacygrad and Pacholczak 2010]. A similar increase was observed in dogwood cuttings after application of AlgaminoPlant [Pacholczak et al. 2012]. In this study, auxin, AlgaminoPlant and Route increased the free amino acids content in both years.

Proteins play multiple functions in plants: structural, metabolic, transport and storage. As enzymes, they participate in multiple reactions and are responsible for a dynamic balance within a cell [Bojarczuk 1997]. Higher content of soluble proteins were reported in *Hosta* sp. and *Bergenia cordifolia* treated with biostimulators [Krajewska and Latkowska 2008]. Increases in free amino acids and soluble proteins after zinc applications were reported by Tarraf et al. [1999], Nahed et al. [2007] and Farahat et al. [2007], the latter on *Cupressus sempervirens.* In this study, auxin, AlgaminoPlant and Route increased the soluble protein contents in both years.

The results suggest that the use of biostimulators induces biochemical and physiological changes which may be responsible for the increased ability of cuttings to regenerate roots. This means that it is worth to consider their application in nursery practice, which should, however, be proceeded by broader studies on the mechanisms of their action.

CONCLUSIONS

1. Treatments with Rhizopon AA and the IBA water solution enhanced a percentage and degree of rooting in cuttings of *Cotinus coggygria* Scop. 'Royal Purple' in both experimental seasons.
2. Treatments with AlgaminoPlant and Route increased a degree and a percentage of rooting in cuttings of smoke tree in 2013. The higher doses of these biostimulators proved more effective, being comparable to IBA.
3. Generally, treatments with both biostimulators tended to increase the rate of photosynthesis and respiration in cuttings.
4. The foliar applications of AlgaminoPlant and Route increased the contents of total and reducing sugars, free amino acids and soluble proteins in cuttings in both years while the chlorophyll *a* + *b* content was increased only in 2013.

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FIZJOLOGICZNE ASPEKTY ROZMNAZANIA PERUKOWCA PODOLSKIEGO (*Cotinus coggygria* Scop. 'Royal purple') PRZEZ SADZONKI PĘDOWE

Streszczenie. Biostymulatory są preparatami stosowanymi w celu poprawy wzrostu i rozwoju roślin, zwłaszcza w warunkach stresujących. Celem pracy było sprawdzenie działania dwóch biostymulatorów: AlgaminoPlant (0,2%) i Route (0,1%) na ukorzenianie perukowca podolskiego 'Royal Purple' i ich wpływu na zmiany biochemiczne oraz wymianę gazową u sadzonek pędowych. Sadzonki podczas ukorzenienia opryskiwane były jedno-, dwu- lub trzykrotnie, w odstępach tygodniowych, wodnym roztworem biostymulatorów. Skuteczność preparatów porównano z tradycyjnie stosowanymi środkami w produkcji szkółkarskiej, czyli pudrowym ukorzeniaczem Rhizopon AA, zawierającym syntetyczną auksyny IBA (2%) lub roztworem wodnym IBA (200 mg dm^{-3}) stosowanym dolistnie. Potrójne traktowanie sadzonek AlgaminoPlantem i jednokrotne zastosowanie Route zwiększyło stopień ich ukorzeniania w stosunku do kontroli. W sadzonkach opryskiwanych jednokrotnie AlgaminoPlantem i dwukrotnie Route, zaobserwowano zwiększoną fotosyntezę. Jednokrotne i trzykrotne opryskiwanie AlgaminoPlantem spowodowało wzrost intensywności oddychania sadzonek. Zastosowanie w/w biostymulatorów wpłynęło na wzrost zawartości chlorofilu, cukrów ogólnych i redukujących. Na podstawie uzyskanych wyników wnioskuje się, że stosowanie biostymulatorów może powodować biochemiczne i fizjologiczne zmiany u sadzonek, które zwiększają ich zdolność do regeneracji korzeni, dlatego ich wykorzystanie powinno być zalecane w praktyce szkółkarskiej.

Słowa kluczowe: ukorzenianie, fotosynteza, oddychanie, węglowodany, białka

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