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INFLUNCE OF TIME OF BENZYLADENINE APPLICATION ON ROOTING OF CUTTINGS AND SUBSEQUENT DEVELOPMENT OF *Portulaca umbraticola* Kunth

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Abstract. Auxins are main promoters of rooting. Cytokinins are considered as auxin antagonists in adventitious root formation, but their role in this process depends on a number of factors, such as concentration and the phase of treatment. Regardless of their role in rhizogenesis, cytokinins stimulate lateral shoot development. The aim of the experiment was to determine the effect of BA applied in different time of rooting and its cooperation with NAA on *Portulaca* cuttings and subsequent growth of plants. Stem cuttings of *Portulaca umbraticola* were treated with BA or BA and NAA in different concentrations and time of BA application (0; 2 and 5 days after placing in medium). BA, administered at the beginning of rooting, negatively influenced percentage of rooted cuttings, while applied two days later stimulated rooting. BA positively determined lateral shoot length and number on cuttings. Application of BA with NAA stimulated root development, but negatively affected the axillary shoot outgrowth. Considering the effect of BA treatment on rooting and branching of *Portulaca* cuttings the most advantages combinations occurred to be BA applied after 2 days of rooting.

Key words: adventitious roots, lateral shoots, cytokinin, BA, auxin, NAA

INTRODUCTION

Adventitious root formation is an indispensible condition in vegetative propagation of plants. Among numerous genetic, physiological, physical and chemical factors controlling both, lateral and adventitious, root regeneration, plant hormone regulation seems to play a key role [Schiefelbein and Benfey 1991, De Klerk et al. 1999, Aloni et al. 2006]. Stimulation of root initiation and development is governed by auxins [Blakesley et al. 1991]. In the course of rooting, endogenous IAA is transported basipetally from shoot apex to the base of cutting, where it stimulates rhizogenesis.

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Blocking of auxins transportation, e.g. by removing apical meristem as well as by triiodobenzoic acid (TIBA) or naphthylophthalmic acid (NPA) inhibits rooting [Koukourikou-Petridou and Bangerth 1997, Casimiro et al. 2001, Li et al. 2008]. Similar results are obtained when treating roots with exogenous cytokinins, which are considered as auxin antagonists in the process of adventitious root formation [Van Staden and Harty 1988, Hartmann et al. 2002]. However, their role in this process is dependent on a number of factors, which proves complex character of cytokinin involved rooting regulation. Positive results of cytokinin application on the number of lateral and adventitious roots were most often obtained when plant or cuttings were treated with solutions of low concentrations, for instance 10^{-7} mol dm^{-3} or lower than 3×10^{-10} mol dm^{-3} in case of zeatin and equal or lower than 10^{-5} mol dm^{-3} in case of isopentenyladenine (2-iP) and kinetin [Wightman et al. 1980, Fabijan et al. 1981, Biddington and Dearman 1982, Van Staden and Harty 1988]. Another very important factor affecting cytokinin regulation is the stage of rooting. More satisfactory results featured the use of cytokinins in later stages of rooting, yet they were also related to the site of application, as well as the presence of auxins [Mohammed 1980, Van Staden and Harty 1988, De Klerk et al. 1995].

Regardless their role in the process of rooting, cytokinins stimulate development of lateral and adventitious shoots. This property of cytokinins is utilized in cultivation of ornamental plants to obtain considerably branched plants, as well as in plant propagation in *in vitro* cultures. Also in this process cytokinins show antagonistic activity in relation to auxins [Werner and Schmülling 2009]. High level of cytokinins at low level of auxins favors development of lateral shoots, while high ratio values of auxins to cytokinins determines apical dominance [Li and Bangerth 2003]. Possible stimulation of lateral shoot development in cuttings could prove to be very advantageous for plant producers. Better – branched plants are highly desirable in horticultural practice due to their more significant decorative value, moreover, higher number of shoots is connected with more abundant flowering. However, not much has been known about the effect of cytokinins on shoot development in cuttings. In research conducted so far, main stress has been put on the question of rhizogenesis, without concentrating on possible application of those regulators to the development of above – ground parts of cuttings.

The aim of the experiment was to determine the effect of application of benzyladenine in different time of rooting as well as the evaluation of its cooperation with auxins on *Portulaca umbraticola* Kunth plants from the stage of propagation by cuttings. From practical point of view the most interesting purpose of the study was the possibility of obtaining well branched plants as a final product of cultivation.

MATERIAL AND METHODS

The experiment with propagating *Portulaca umbraticola* Kunth by cuttings was carried out in the greenhouse of Department of Horticulture, Wroclaw University of Environmental and Life Sciences, Poland. It was established on the 15th of April 2009 and 2010. Apical stem cuttings, 4 cm in length, were treated with benzyladenine (BA) or benzyladenine with naphthalene-1-acetic acid (BA + NAA) in following combinations (g dm^{-3}):

BA: 0.1 (5.5×10^{-4} mol dm^{-3}); 0.2 (10^{-3} mol dm^{-3})

NAA + BA: NAA 0.5 (2.7×10^{-3} mol dm^{-3}) + BA 0.1; NAA 0.5 + BA 0.2; NAA 1.0 (5.4×10^{-3} mol dm^{-3}) + BA 0.1; NAA 1.0 + BA 0.2.

The last combination were control cuttings treated with water. BA was applied by spraying on leaves immediately after placing the cuttings in soil and 2 or 5 day later. NAA was applied by quick-dip method: basal ends of the cuttings were dipped in solutions for 5 second before placing in soil.

The soil consisted of white peat, pine bark and perlit 3:1:1; V:V:V, pH 6.4. It was heated to the temperature of 21°C. Low plastic tunnels were installed over the cuttings. The experiment was established in a one factorial design in 3 replications, per 10 cuttings in each replication. The measurements of cuttings were taken after 4 weeks of rooting. Then the rooted cuttings were planted into pots, in peat substrate of pH 6.47 containing (in mg dm^{-3}): $N\text{-}NO_3^-$ 145, P 119, K 263, Mg 90, Ca 1120 and placed in non-heated glasshouse. The experiment was established in 4 replications, per 5 plants in each. After 4 weeks of cultivation first and second axillary shoots were counted as well as their length was measured.

Data of the study were subjected to analysis of variance, and least significant differences between means were calculated by the Tukey test at $p = 0.05$. Data concerning the percentage of rooted cuttings were formerly transformed according to Bliss function.

RESULTS

Independently on the year of experiment, the time of benzyladenine application had a significant influence on the rooting and development of *Portulaca umbraticola* cuttings. Regardless introduction of NAA and its concentration, benzyladenine, administered at the beginning of rooting process, did negatively affect percentage of rooted cuttings, while the ones treated with BA two days after excision rooted in maximum percentage. Application of BA five days after rooting resulted in decreased number of rooted cutting, but this effect was weaker comparing to direct BA treatment. The strongest contribution to described dependence resulted from the findings obtained in the second year of experiment (tab. 1). In the first cycle of the experiment, almost none of the treatments influenced the percentage of rooting, as the cuttings from all combinations, apart from few combinations with BA in concentration 0.1 g dm^{-3}, rooted in the maximum percentage. Similar relation was observed in the case of the number of adventitious roots on cuttings. The highest number of roots was formed by BA – treated cuttings after 2 days of rooting, although in cuttings treated with benzyladenine solely the mentioned effect was less pronounced and it remained statistically insignificant. In almost all combinations NAA + BA, except for NAA 0.5 and BA 0.2 g dm^{-3}, the number of roots on cuttings treated with BA after 2 days of rooting increased by at least 75% in comparison to control cuttings (tab. 1). The positive result on root number was also observed after treatment with NAA 0.5 + BA 0.1 g dm^{-3}. The remaining combinations did not influence this feature.

All the examined combinations, except for benzyladenine introduced after 2 days of rooting and for NAA 1.0 with BA 0.1 g dm^{-3} applied at the beginning of rooting, proved

to be of an inhibiting effect on the height of cuttings (tab. 2). Both regulators subjected to investigation slightly influenced the number of lateral shoots on cuttings. Only four combinations: BA 0.1 g dm^{-3} introduced after 2 days and BA 0.2 g dm^{-3}, independently on the time of treatment, did advantageously affect the number of axillary shoots on cuttings. The effect of the examined growth regulators on summary length of lateral shoots in cuttings followed slightly different pattern. Significantly longer shoots were produced by cuttings treated exclusively with benzyladenine of 0.1 g dm^{-3} concentration, applied after 5 days and of 0.2 g dm^{-3} concentration introduced after 2 days of rooting. A satisfactory effect on this property was also obtained by simultaneous treating cuttings with NAA 0.5 and BA 0.1 g dm^{-3} directly after placing the cuttings in the soil (tab. 2).

Table 1. The influence of NAA and time of BA application on rooting of cuttings of *Portulaca umbraticola* Kunth

Tabela 1. Wpływ NAA i czasu traktowania BA na ukorzenianie sadzonek portulaki cieniolubnej *Portulaca umbraticola* Kunth

Growth regulators (g dm^{-3}) Regulatory wzrostu (g dm^{-3})	Day of BA treatment Dzień oprysku BA	Feature –Cecha					
		rooting* (%) ukorzenianie* (%)			number of roots liczba korzeni		
		2009	2010	mean średnia	2009	2010	mean średnia
Control – Kontrola	---	90.0	90.0	90.0	13.0	12.0	12.5
BA 0.1	0	77.7	71.6	74.6	7.7	18.9	13.3
	2	90.0	90.0	90.0	15.9	21.7	18.8
	5	83.9	83.9	83.9	13.7	12.1	12.9
BA 0.2	0	90.0	64.6	77.3	14.0	18.3	16.2
	2	90.0	90.0	90.0	17.1	18.4	17.8
	5	90.0	83.9	87.0	14.1	12.5	13.3
NAA 0.5 + BA 0.1	0	66.6	66.1	66.4	12.9	30.1	21.5
	2	90.0	90.0	90.0	11.2	36.6	23.9
	5	90.0	75.0	82.5	13.6	9.3	11.5
NAA 0.5 + BA 0.2	0	90.0	71.6	80.8	13.5	22.0	17.8
	2	90.0	90.0	90.0	13.7	10.3	12.0
	5	90.0	90.0	90.0	13.0	16.8	14.9
NAA 1.0 + BA 0.1	0	90.0	83.6	86.8	15.5	15.5	15.5
	2	90.0	90.0	90.0	11.5	32.7	22.1
	5	90.0	75.0	82.5	14.5	14.1	14.3
NAA 1.0 + BA 0.2	0	90.0	83.6	87.0	14.9	19.0	17.0
	2	90.0	90.0	90.0	14.0	30.4	22.2
	5	90.0	77.7	83.5	15.2	17.1	16.2
LSD – NIR: for treatment – dla sposobu traktowania			2.8			7.0	
for treatment × year – dla sposobu traktowania × rok			3.9			9.5	

* Data modified according to Bliss' function – Dane zmodyfikowane wg funkcji Blissa

Table 2. The influence of NAA and time of BA application on shoot development on cuttings of *Portulaca umbraticola* Kunth
Tabela 2. Wpływ NAA i czasu traktowania BA na rozwój pędów na sadzonkach portulaki cieniolubnej *Portulaca umbraticola* Kunth

Growth regulators (g dm^{-3}) Regulatory wzrostu (g dm^{-3})	Day of BA treatment Dzień oprysku BA	Feature – Cecha								
		height of cuttings (mm) wysokość sadzonek (mm)			number of lateral shoots liczba pędów bocznych			sum of lateral shoot length(mm) suma długości pędów bocznych (mm)		
		2009	2010	mean średnia	2009	2010	mean średnia	2009	2010	mean średnia
Control – Kontrola	---	112.1	138.5	125.3	1.3	4.1	2.7	6.0	23.1	14.6
BA 0.1	0	89.3	89.2	89.3	2.0	3.5	2.8	17.8	12.3	15.1
	2	93.2	147.1	120.2	1.8	5.8	3.8	12.7	26.2	19.5
	5	95.4	127.0	111.2	2.2	3.1	2.7	8.1	35.6	21.9
BA 0.2	0	105.5	85.6	95.6	3.4	4.2	3.8	17.5	19.8	18.8
	2	91.4	131.1	113.3	2.1	5.1	3.6	14.1	37.1	25.6
	5	90.0	119.7	93.6	2.6	4.1	3.4	11.9	27.0	19.5
NAA 0.5 + BA 0.1	0	86.5	101.1	91.3	0.8	1.5	1.2	4.6	17.2	21.8
	2	81.6	119.5	100.7	0.6	3.6	2.1	2.0	21.9	12.0
	5	88.5	82.7	85.6	0.5	2.4	1.5	1.4	12.6	7.0
NAA 0.5 + BA 0.2	0	102.4	107.7	105.1	1.4	3.3	2.4	3.5	25.3	14.4
	2	66.6	76.2	71.4	0.3	1.1	0.7	3.6	19.8	11.7
	5	89.1	89.1	89.1	0.7	1.3	1.0	3.8	3.8	3.8
NAA 1.0 + BA 0.1	0	112.4	113.6	113.0	0.7	1.2	1.0	1.7	1.7	1.7
	2	75.8	77.7	76.8	0.6	1.1	0.9	1.3	8.7	5.0
	5	37.4	93.9	65.7	0.4	0.6	0.5	1.4	6.9	4.2
NAA 1.0 + BA 0.2	0	74.6	72.8	73.7	0.6	1.3	1.0	2.5	8.1	5.3
	2	78.4	76.1	77.3	1.5	4.4	3.0	5.8	10.6	8.2
	5	50.1	90.9	70.5	0.7	1.4	1.1	1.1	6.8	4.0
LSD – NIR: for treatment – dla sposobu traktowania			12.8			0.9			5.6	
for treatment × year – dla sposobu traktowania × rok			18.1			1.3			7.9	

Table 3. The influence of NAA and time of BA application on cuttings on subsequent growth of young plants of *Portulaca umbraticola* Kunth
Tabela 3. Wpływ NAA i czasu traktowania BA w trakcie ukorzeniania na wzrost następczy młodych roślin portulaki cieniolubnej *Portulaca umbraticola* Kunth

Growth regulators (g dm^{-3}) Regulatory wzrostu (g dm^{-3})	Day of BA treatment Dzień oprysku BA	Feature – Cecha								
		lenght of main shoot (mm) długość pędu głównego (mm)			number of lateral shoots liczba pędów bocznych			sum of lateral shoot length(mm); suma długości pędów bocznych (mm)		
		2009	2010	mean średnia	2009	2010	mean średnia	2009	2010	mean średnia
Control – Kontrola	---	159.9	266.4	163.2	9.3	11.6	10.5	42.4	120.3	81.4
BA 0.1	0	153.8	220.5	187.2	14.2	20.1	17.2	74.6	125.9	100.3
	2	129.6	236.0	182.8	12.4	19.1	15.8	51.0	139.8	95.4
	5	131.5	288.0	209.8	10.9	14.4	12.7	59.8	137.0	98.4
BA 0.2	0	155.8	220.9	188.4	11.7	16.1	13.9	59.6	131.0	95.3
	2	171.1	217.7	194.4	8.6	16.4	12.5	59.9	109.6	95.3
	5	130.5	286.0	208.3	8.8	16.7	12.8	43.4	141.2	92.3
NAA 0.5 + BA 0.1	0	122.2	195.3	158.8	8.3	6.1	7.2	21.6	62.3	42.0
	2	109.6	232.3	171.0	10.1	6.7	8.4	24.2	116.5	70.4
	5	111.8	247.9	179.9	10.2	8.0	9.1	22.1	94.2	58.2
NAA 0.5 + BA 0.2	0	136.2	196.4	166.3	9.5	10.0	9.8	32.5	58.3	45.4
	2	85.3	256.1	170.7	10.0	8.4	9.2	22.1	90.2	56.2
	5	83.2	219.8	151.5	10.9	6.5	8.7	21.3	66.8	44.1
NAA 1.0 + BA 0.1	0	106.7	212.5	159.6	10.8	10.4	10.6	22.4	49.1	35.8
	2	82.4	227.4	154.9	10.8	8.3	10.1	23.1	82.9	53.0
	5	96.5	237.0	166.8	9.4	6.8	8.1	29.0	78.9	54.0
NAA 1.0 + BA 0.2	0	86.9	216.5	151.7	9.4	7.6	8.5	24.9	89.3	51.9
	2	88.4	273.1	180.8	8.5	14.4	11.5	37.0	146.8	91.9
	5	86.9	194.8	140.9	8.9	7.7	8.3	22.2	72.3	47.3
LSD – NIR:										
for treatment – dla sposobu traktowania			14.0			1.7			12.5	
for treatment × year – dla sposobu traktowania × rok			19.8			2.3			17.7	

The way of treatment did significantly influence subsequent growth of plants obtained from cuttings subjected to NAA and BA, in concentrations taken to the research, in both years of research, although more intensive plant growth was recorded in the second year of the experiment (tab. 3). Treating the cuttings with benzyladenine proved to be of a stimulating effect on elongation of the main shoot, although the best results were obtained when BA was introduced 5 days after placing cuttings in rooting medium. Introduction of BA combined with NAA did not affect shoot length, except for combination of NAA 1.0 with BA 0.2 applied 5 days after placing the cuttings in the soil, which inhibited elongation of the main shoot and NAA 1.0 + BA 0.2 after 2 days as well as NAA 0.5 + BA 0.1 after 5 days of rooting which stimulated main shoot development. Advantageous effect of exclusive use of benzyladenine on the number and summary length of lateral shoots in cuttings could be observed. The mentioned effect took place in all BA combinations, nevertheless, the highest number of shoots was produced by plants treated with BA of 0.1 concentration administered on the day of rooting or 2 days later (tab. 3). Treating *Portulaca umbraticola* cuttings with BA and NAA together negatively influenced the development of above – ground parts in young plants, i.e. the number and length of lateral shoots.

DISCUSSION

From practical point of view adventitious rooting is one of the stages of plant production, within which treating cuttings with growth regulators at the beginning of the process results in the occurrence of adventitious roots after the process is completed. On the other hand, numerous genetic, physiological and cytochemical examinations present the process of root development, both adventitious and lateral ones, as a sequence of interdependent phases, expressed, among others, as changes in hormone levels and diverse response to hormonal signals [De Klerk et al. 1995, Li et al. 2009].

Although duration and definitions of particular stages of adventitious and lateral root development are interpreted by researchers in a slightly different way, there is no argument regarding the sequence of stages [De Klerk et al. 1995, Taylor and van Staden 1997, Ermel 2000]. There are usually distinguished the stage of initiation, including differentiation and induction, as well as the stage of expression, featuring cell division, organizing of root meristem and root elongation until a root occurs on a shoot surface. Early stages of root primordia formation, completed with initial cell divisions, involve activation of sequential genes, among which numerous are expressed in both, lateral and adventitious root primordia. They are, for example: Hydroxyproline-rich Glycoproteine gene (HRGPnt3) in tobacco, expressed instantly after the first cell division and Lateral Root Primordium-1 gene (LPR1), turned off prior to root emergence from parent tissue in *Arabidopsis* [Vera et al. 1994, Smith and Fedoroff 1995, Li et al. 2009]. Some of them, like Root System Inducible-1 (RSI-1) gene of tomato and Adventitious Rootless1 (ARL1) in rice are induced by auxin [Taylor and Scheuring 1994, Liu et al. 2005]. High level of IAA in the tissues of cutting base at the same time and high sensitivity to exogenous auxins [Gaspar et al. 2003] corroborates such dependence. During early stages of rooting the concentration of natural cytokinins in the tissues present at cutting base

remains at relatively constant, low level [Taylor and van Staden 1997]. During this phase exogenous cytokinins inhibit rhizogenezis, especially when they are administered in high concentrations [Wightmann et al. 1980, Laplaze et al. 2007]. Dello Ioio et al. [2007] give evidence that mechanism of such inhibition involves suppression of meristematic cell differentiation at the transition zone. In lateral root development high levels of cytokinins disrupt their initiation as well as regular pattern of cell division [Laplaze et al. 2007]. Along with the proceeding development of primordium, the changes in hormone levels are observed, as well as in tissue sensitivity to endogenous and exogenous growth regulators. Rapid increase in cytokinin concentration due to their synthesis by developing root meristem could be observed at the stage of elongation and emerging of roots [Taylor and Van Staden 1997]. Despite this natural self-sufficiency for these hormones, exogenous cytokinin, applied at this stage of rooting, positively affect root elongation process [Eriksen 1974, Mohammed 1980, Rani Debi et al. 2005] at the lack of response to auxins [Li et al. 2009].

In the light of discussed relations, from practical point of view, simultaneous treatment of cuttings with auxins and cytokinins is not justified as far as rooting process is concerned. Although auxins introduction should take place just after excision of shoot, yet treatment with cytokinins seems to be the most advantageous if it is delayed by 48 to 72 hours [De Klerk et al. 1995]. This statement can be confirmed by conducted research. The highest percentage of rooting and number of roots was obtained in *Portulaca umbraticola* cuttings treated with BA after two days of rooting, regardless treatment with NAA, while BA, applied directly after placing the cuttings in a growing medium, negatively influenced both properties described.

Relation between auxins and cytokinins also play a significant role in forming plant shape. Branching pattern involved in plant architecture is based on dormant axilliary buds, which can be reactivated to form a shoot [Ongaro and Leyser 2008, Werner and Schmülling 2009]. The process is regulated by numerous environmental signals, such as light spectrum and intensity or ambient temperature, allowing the plant to adopt its shape to the prevailing conditions, as well as by the action of plant hormones, of which auxin and cytokinin balance is crucial. Auxins produced in apical shoot meristem are transported basipetaly in the shoot, where they suppress axillary bud outgrowth. It is suggested that auxins function through reduction of local cytokinin biosynthesis [Nördstrom et al. 2004, Tanaka et al. 2006]. Removing the apical bud induces cytokinin accumulation in auxiliary buds and releases them from dormancy [Shimizu-Sato et al. 2009]. Such intervention is commonly used in commercial production in order to receive well-branched plants, thus it is considerably work-consuming. This research supports the thesis that similar effect may be received by exogenous application of cytokinins [Edson et al. 1991, Nowak and Grzesik 1997, Ongaro and Leyser 2008]. Contrary to investigation of Wróblewska and Bąbelewski [2010], described effect was not significant in the case of cuttings, while it became more profound in plants originating from them. Unlike the effect of BA on rooting, positive influence of this growth regulator on the number and length of lateral shoots did not depend on the time of application, as well as on its concentration. The mechanism of cytokinin activity in shoots may be similar to that controlling shoot apical meristem development, in which cytokinins are

responsible for sustainability of proliferative meristem activity [Doerner 2007, Kyozuka 2007].

The possibility of hormonal control of cutting development with auxins and cytokinins together is a complex issue, as both groups of regulators act in an antagonistic way in shoot and root development [Gaspar et al. 2003]. Considering the influence of BA treatment on rooting and branching of *Portulaca umbraticola* cuttings suggests that the use of BA to enhance the development of plants might be possible if it is applied 2 days after the onset of propagation.

CONCLUSIONS

1. BA positively determined lateral shoot development of *Portulaca umbraticola* cuttings and obtained from them young plants. Regardless the time of BA treatment and its concentration, the shoots were longer and more numerous. Application of BA together with NAA did not give such beneficial results. Yet these treatments stimulated root development, they negatively affected the axillary shoot outgrowth.

2. Considering the influence of BA on *Portulaca umbraticola* cuttings the most advantageous treatment was application of BA in both: 0.1 and 0.2 g dm^{-3} concentrations two days after placing the cuttings in the soil. Such treatment resulted in the highest percentage of rooted cuttings and satisfactory number of adventitious roots per cutting, it also determined good quality of aerial parts of cuttings, expressed by high axillary shoot number of considerable length.

REFERENCES

Aloni R., Aloni E., Langhans M., Ullrich C., 2006. Role of cytokinin and auxin in shaping root architecture, regulating vascular differentiation, lateral root initiation, root apical dominance and root gravitropism. Ann. Bot. 97, 883–893.

Biddington N.L., Dearman A.S., 1982. The involvement of the root apex and cytokinins in the control of lateral root emergence in lettuce seedlings. Plant Growth Regul. 1, 183–193.

Blakesley D., Weston G.D., Hall J.F., 1991. The role of endogenous auxin in root initiation. I. Evidence from studies on auxin aplication, and analysis of endogenous levels. Plant Growth Regul. 10, 341–353.

Casimiro I., Marchant A., Bhalerao R.B., Beeckman T., Dhooge S., Swarup R., Graham N., Inzé D., Sandberg G., Casero P.J., Bennett M., 2001. Auxin transport promotes *Arabidopsis* lateral root initiation. Plant Cell 13, 843–852.

Dello Ioio R., Linhares F.S., Scacchi E., Casamitjana-Martinez E., Heidstra R., Costantino P., Sabatini S., 2007. Cytokinins determine *Arabidopsis* root-meristem size by controlling cell differentiation. Curr. Biol. 17(8), 678–82.

De Klerk G.J., Keppel M., Ter Brugge J., Meekes H., 1995. Timing of the phases in adventitious root formation aplle microcuttings. J. Exp. Bot. 46, 965–972.

De Klerk D.J., van der Krieken W., de Jong J.C., 1999. Review: The formation of adventitious roots, new concepts, new possibilities. Vitro Cell. Dev. Biol. Plant 35, 189–199.

Doerner P., 2007. Plant Meristems: Cytokinins – The Alpha and Omega of the Meristem. Curr. Biol. 17(9), 321–323.

Edson J.L., Wenny D.L., Fins L., 1991. Inducing long-shoot growth for vegetative propagation of western larch. New Forests 5, 51–60.

Ermel F.F., Vizoso S., Charpentier J.P., Jay-Allemand C., Catesson A.M., Couée I., 2000. Mechanisms of primordium formation during adventitious development from walnut cotyledon explants. Planta 211, 563–574.

Eriksen E.N., 1974. Root formation in pea cuttings. III. The influence of cytokinin at different developmental stages. Physiol. Plant. 30, 163–167.

Fabijan D., Taylor J.S., Reid D.M., 1981. Adventitious root formation in hypocotyls of sunflower (Helianthus annuus) seedlings. II. The role of gibbrellins, cytokinins, auxins and ethylene. Physiol. Plant. 53, 578–588.

Gaspar T., Kevers C., Faivre-Rampant O., Crèvecoeur M., Penel C., Greppin H., Dommes J., 2003. Changing concepts in plant hormone action. Vitro Cell. Dev. Biol. Plant. 39, 85–106.

Hartmann H.T., Kester D.E., Davies F.T., Geneve R.L., 2002. Principles of propagation by cuttings. In: Plant propagation, principles and practices. Prentice Hall, Upper Saddle River, New Jersey, 278–291.

Koukourikou-Petridou M.A., Bangerth F., 1997. Effect of changing the endogenous concentration of auxins and cytokinins and the production of ethylene in pea stem cuttings on adventitious root formation. Plant Growth Regul. 22, 101–108.

Kyozuka J., 2007. Control of shoot and root meristem function by cytokinin. Curr. Op. Plant Biol. 10, 442–446.

Laplaze, L., Benkova E., Casimiro I., Maes L., Vanneste S., Swarup R., Weijers D., Calvo V., Parizot B., Herrera-Rodriguez M.B., Offringa R., Graham, N., Doumas P., Friml J., Bogusz D., Beeckman T., Bennett M., 2007. Cytokinins act directly on lateral root founder cells to inhibit root initiation. Plant Cell 19, 3889–3900.

Li C., Bangerth F., 2003. Stimulatory effect of cytokinins and interaction with IAA on the release of lateral buds of pea plants from apical dominance. J. Plant Physiol. 160, 1059–1063.

Li Y.H., Chen Q.Z., Xiao J.N., Chen Y.F., Li X.J., Staehelin C., Huang X.L., 2008. Characteristics of adventitious root formation in cotyledon segments of mango (*Mangifera indica* L. cv. Zihua): two induction patterns, histological origins and the relationship with polar auxin transport. Plant Growth Regul. 54, 165–177.

Li S.W., Xue L., Xu S., Feng H., An L., 2009. Mediators, genes and signaling in adventitious rooting. Bot. Rev. 75, 230–247.

Liu H., Wang S., Yu X., Yu J., He J., Zhang S., Shou H., Wu P., 2005. ARL1, a LOB-domain protein required for adventitious root formation in rice. Plant J. 43, 47–56.

Mohammed S., 1980. Root formation in pea cuttings: effects of combined application of auxin and cytokinin at different developmental stages. Biol. Plant. 22 (3), 231–236.

Nördstrom A., Tarkowski P., Tarkowska D., Norbeak R., Åstot C., Dolezal K., 2004. Auxin regulation of cytokinin biosynthesis in *Arabidopsis thaliana*: A factor of potential importance for auxin-cytokinin-regulated development. Proc. Natl. Acad. Sci. USA 101, 8039–8044.

Nowak J., Grzesik M., 1997. Regulatory roślinne w uprawie roślin ozdobnych. W: Regulatory wzrostu i rozwoju roślin, Jankiewicz L.S. (red.). Wyd. Nauk. PWN, Warszawa, 111–136.

Ongaro V., Leyser O., 2008. Hormonal control of shoot branching. J. Exp. Bot. 59, 67–74.

Rani Debi B., Taketa S., Ichii M., 2005. Cytokinin inhibits lateral root initiation but stimulates lateral root elongation in rice (*Oryza sativa*). J. Plant Physiol. 162, 507–515.

Schiefelbein, J.W., Benfey P.N., 1991. The development of plant roots, new approaches to underground problems. Plant Cell 3, 1147–1154.

Shimizu-Sato S., Tanaka M., Mori H., 2009. Auxin-cytokinin interactions in the control of shoot branching. Plant Mol. Biol. 69, 429–435.

Smith D.L., Fedoroff N.V., 1995. *LRP1*, a gene expressed in lateral and adventitious root primordia of *Arabidopsis*. Planr Cell 7, 735–745.

Tanaka M., Takei K., Kojima M., Sakakibara H., Mori H., 2006. Auxin controls local cytokinin biosynthesis in the nodal stem in apical dominance. Plant J. 45, 1028–1036.

Taylor B.H., Scheuring C.F., 1994. A molecular marker for lateral root initiation: the RSI-1 gene of tomato (*Lycopersicon esculentum* Mill.) is activated in early lateral root primordia. Mol. Gen. Genet. 243, 148–157.

Taylor J.L.S., van Staden J., 1997. Variation in the level and type of cytokinin with the stage of root development in *Impatiens walleriana* Hook. f. stem cuttings. Plant Growth Regul. 22, 175–180.

Van Staden J., Harty A.R., 1988. Cytokinins and Adventitious Root Formation. W: Adventitious root formation in cuttings, Davies T.D., Haissig B.E., Sankhla N. (red.). Dioscorides Press, Portland, Oregon, 185–201.

Vera P., Lamb C., Doerner P.W., 1994. Cell-cycle regulation of hydroxyproline-rich glycoprotein HRGPnt3 gene expression during the initiation of lateral root meristems. Plant J. 6, 717–727.

Wightman F., Schneider E.A., Thimman K., 1980. Hormonal factors controlling the initiation and development of lateral roots. II. Effect of exogenous growth factors on lateral root formation in pea roots. Physiol. Plant. 49, 304–314.

Werner, T., Schmülling T., 2009. Cytokinin action in plant development. Curr. Op. Plant Biol. 12, 527–538.

Wróblewska K., Bąbelewski P., 2010. The effect of benzyladenine and naphthalene acetic acid on rooting and subsequent growth of *Portulaca umbraticola* Kunth. Folia Hort. Ann. 22(2), 39–44.

WPŁYW TERMINU STOSOWANIA BENZYLADENINY NA UKORZENIANIE SADZONEK I ROZWÓJ NASTĘPCZY PORTULAKI CIENIOLUBNEJ *Portulaca umbraticola* Kunth

Streszczenie. Auksyny są głównymi stymulatorami ukorzeniania. Cytokininy uważane są za ich głównych antagonistów w procesie powstawania korzeni przybyszowych, ale efekt ich działania w tym procesie zależy on wielu czynników, w tym od stężenia oraz fazy ukorzeniania. Niezależnie od ich roli w procesie ukorzeniania, cytokininy stymulują rozwój pędów bocznych. Celem doświadczenia było określenie wpływu benzyloadeniny podawanej w różnych terminach ukorzeniania oraz jej współdziałania z NAA na sadzonki portulaki oraz następczy wzrost roślin. Sadzonki pędowe portulaki cieniolubnej zostały potraktowane BA oraz BA z NAA w różnych stężeniach i terminach aplikacji BA (0; 2 i 5 dni po umieszczeniu w podłożu). BA podawana na początku ukorzeniania negatywnie wpłynęła na liczbę ukorzenionych sadzonek wyrażoną w procentach, podczas gdy podawana 2 dni później stymulowała ich ukorzenianie. BA pozytywnie wpłynęła na liczbę i długość pędów bocznych na sadzonkach. Traktowanie sadzonek BA z NAA stymulowało ukorzenianie, ale hamowało rozwój pędów bocznych. Biorąc pod uwagę wpływ traktowania BA na ukorzenianie i rozgałęzianie sadzonek portulaki cieniolubnej, najkorzystniejszy wpływ wywarły kombinacje z BA podawaną 2 dni po rozpoczęciu ukorzeniania.

Słowa kluczowe: korzenie przybyszowe, pędy boczne, cytokinina, BA, auksyna, NAA

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