Peculiarities of rooting ability and formation of *Ribes atropurpureum* root system on treatment of grafts with growth regulators

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Abstract. The data on the rooting ability and peculiarities of root system formation of hard-wood and soft-wood cuttings of *Ribes atropurpureum* under the action of growth regulators are presented. The positive influence of humat potassium, tellura-M, and phoenix in the concentration of 0.5–1% on branching and root length of different orders of ramification in hard-wood and soft-wood cuttings was established. Hard-wood cuttings formed longer roots of orders I and II of ramification, but branching was poorer than that in soft-wood cuttings.

Key words: growth regulators, hard-wood and soft-wood cuttings, root system, *Ribes atropurpureum*

INTRODUCTION

Red currant is an industrial crop in the USA, Canada, Poland, Germany, Hungary, France, Holland and Belgium (Bayanova, 1996). In Russia, including Siberia, it is grown mainly in private gardens. Among wild Siberian red currants *R. atropurpureum* C.A.Meyer and *R. hispidulum* (Jancz.) Pojark. are of the greatest interest for introduction and breeding, but have not yet been extensively used in breeding. 'Obskoi zakat' is the only cultivar created by hybridization of 'Red cross' cultivar and a selected natural Altai form of *R. atropurpureum* (Kravtsova at al., 1971).

Research on the introduction and breeding of *R. atropurpureum* is carried out in CSBG because this species is characterized by high yield, large berries, long racemes, high content of anthocyans, pectins and vitamin C, resistance to powdery mildew (*Sphaerotheca mors-uvae* Berk. et Curt.), blister rust (*Cronartium ribicola* Dietr.), doubling and currant bud mite - *Cecidophyes ribis* Westw. (Voshchilko, 1971; Kravtsova at al., 1971; Alekseeva, 1988; Bayanova, 1996 and others).

The development of methods of propagation by seed and vegetative propagation, important when introducing new species, have not been developed for *R. atropurpureum.*

Propagation by hard-wood cuttings is a widely-distributed method of vegetative propagation of red currant (Kampuss & Pedersen, 2003). Their rooting ability varies depending on genotypical peculiarities of a cultivar, maturity and age of shoot, and sometimes does not reach 15%. Treatment of hard-wood cuttings with a laser prior to planting increased the rooting ability from 14 to 92% and the volume of root system by 2.6 times. Soft-wood cuttings root more successfully (82–89%) than hard-wood cuttings. Their rooting ability depends on the location of the cutting on a shoot, decreasing from the top (94%) to the base (27%) of a shoot.

It was established (Shcherbakova, 2003) that propagation of red currant cultivars by hard-wood cuttings is the least effective method. The yield of standard saplings increases by 59% when, prior to planting, hard-wood cuttings are moistened by water or treated by indolil-buteric acid at a concentration of 50 mg l^{-1}, soil is mulched with polyethylene film, and polyethylene film greenhouses are used for rooting. The most effective method is propagation by combined cuttings, i.e. by growing cuttings 10–15 cm long with a small piece of last year's shoot. As a result, the yield of standard saplings is 59% of the number of rooted cuttings. The propagation by soft-wood cuttings provides the highest rooting ability (46–92%), but they require supplementary growth in order to obtain standard saplings.

Lately, preparations created on the basis of humic acids (phoenix, tellura-bio, tellura-M, humat sodium, humat potassium, humat calcium), triterpene combinations (silk) and gibberellins (gibbersib) have been widely used for improving plant growth, including the root system, and for increase of plant productivity. The first investigations of the application of the newly developed preparations were carried out on strawberry: 0,05% tellura-bio and 0,005% silk were most preferable for formation of the root system (Lutov at al., 2003).

Due to the need for the introduction and utilization in breeding of promising forms of *R. atropurpureum,* the tasks of our research were to study 1) the rooting ability of hard-wood and soft-wood cuttings, and 2) the peculiarities of root system formation under the action of growth regulators.

MATERIALS AND METHODS

Selected forms of *R. atropurpureum* originating from the Altai Mountains and Salair Range growing in the CSBG experimental plot were used for propagation by cuttings. Cuttings 15–20 cm long were taken from annual hard-wood shoots at the beginning of bud swelling, May 4, 2005. Soft-wood cuttings of the same length were cut from season's shoots at the beginning of lignification, June 23, 2005. The cuttings were tied in bunches and their lower ends dipped into solutions at a depth of 3–4 cm for 20 hours. Variants of treatments: water (control), 0.5% and 1% humat potassium, 0.5% and 1% silk, 0.5% and 1% tellura-M, 0.5% and 1% phoenix. The replication was 4-fold, with ten hard-wood and twenty-five soft-wood cuttings in each. The rooting ability of cuttings, branching, number and length of roots of different order were registered in the middle of September, 2005. Statistical treatment of data was carried out using Statistica 5.0. The influence of growth regulators on the rooting ability of the cuttings was evaluated by the dispersion method. The reliability of the difference among average values of the samples was estimated with the help of t-criterion (Dospekhov, 1968).

RESULTS AND DISCUSSION

After pre-planting treatment of *R. atropurpureum* hard-wood cuttings with root regulators, rootage was low and varied from 0 to 10%, which agrees with G. V. Shcherbakova's data (2003) on red currant cultivars. Four cuttings rooted in the variant of 0.5% tellura-M, in two's in control, 1% humat potassium and 0.5% phoenix and singly in 0.5% humat potassium, 1% silk and 1% phoenix. In 0.5% silk and 1% tellura-M the cuttings did not root. In the variant of 0.5% humat potassium the roots of orders I and II of ramification were formed; roots of orders I, II and III formed in the other variants.

A statistically reliable difference in the number of roots of different orders of ramification in hard-wood cuttings was not established (Table 1). But a tendency towards an increase in the number of roots of orders I–III of ramification is traced in the variants of 1% humat potassium, 0.5% tellura-M, 0.5% phoenix.

Roots of sufficient length were formed in hard-wood cuttings (Table 2, Fig. 1). In comparison with control (4.4±0.7 cm) the roots of order I of ramification were longer in 1% humat potassium (10.8±0.7 cm), 0.5% tellura-M (10.5±0.7 cm) and 0.5% phoenix (7.7±0.6 cm). The reliability of difference among average values of these variants and control was substantial at 0.1% level of significance. Practical t- criterion for the first variant was t_p = 6.8, for the second one - t_p = 5.4, for the third one - t_p = 3.75, for the fourth one - t_p = 4.1 and the theoretical t- criterion was t_{th} = 3.7. Statistically reliably at 0.5% level of significance were noted roots of order II of ramification in 0.5% phoenix (t_p = 2.03 and t_{th} = 2.0). The roots were longer in this variant in comparison with control. In the remaining variants the difference was insignificant. In comparison with control the difference in length of roots of order III of ramification in all variants was insignificant. It is necessary to note that the root system of hard-wood cuttings was formed in different zones of a cutting: in lower node (6 cuttings), in lower and upper nodes (5) and in upper node (2 cuttings).

Soft-wood cuttings of *R. atropurpureum* rooted more successfully than hard-wood cuttings (Table 3), which agrees with G. V. Shcherbakova's data (2003) on red currant cultivars. But dispersion analysis of the data obtained did not reveal a reliable influence of growth regulator on the rooting ability of soft-wood cuttings of *Ribes atropurpureum*, because the practical F- criterion, F_p = 1.40 was smaller than the theoretical one (F_{th} = 2.36).

The roots in soft-wood cuttings ramified significantly more than in hard-wood cuttings. In soft-wood cuttings the roots of orders I–V of ramification were formed in the variant of 1% tellura-M, of orders I–IV of ramification – in the variants of 0.5% humat potassium, 0.5% tellura-M, control, 0.5 and 1% silk, of orders I–III of ramification – in the variants of 0.5 and 1% phoenix.

A statistically reliable difference in the number of roots of different orders of ramification in soft-wood cuttings was not established (Table 4). But a tendency towards an increasing number of roots of orders I–II of ramification is traced in the variants of 0.5% humat potassium, 1% silk and 0.5% tellura-M. The roots of all orders of ramification in soft-wood cuttings were shorter than those in hard-wood cuttings (Table 5, Fig. 2).

Table 1. Formation of a root system in hard-wood cuttings of *Ribes atropurpureum* under the action of growth regulators, 2005.

Variant	Number of rooted cuttings	Number of roots of different orders of ramification in one cutting, cm		
		I order	II order	III order
Control, H_2O	2	$\frac{7,0 \pm 2,8}{5-9}$	$\frac{14,0 \pm 1,4}{13-15}$	4
Humat potassium, 0.5%	1	5	9	0
Humat potassium, 1%	2	$\frac{9,5 \pm 3,5}{7-12}$	$\frac{147,5 \pm 137,9}{50-245}$	96
Silk, 0.5%	0	0	0	0
Silk, 1%	1	3	4	31
Tellura-M, 0.5%	4	$\frac{8,8 \pm 3,8}{5-14}$	$\frac{76,5 \pm 73,9}{7-170}$	$\frac{10,5 \pm 7,8}{5-16}$
Tellura-M, 1%	0	0	0	0
Phoenix, 0.5%	2	$\frac{10,0 \pm 0,0}{10-10}$	$\frac{13,5 \pm 6,4}{9-18}$	300
Phoenix. 1%	1	14	13	22

*numerator - average arithmetic value (M) and its error (m), denominator – limits

In comparison with control (2.8±0.2 cm) in all variants with growth regulators, except 1% humat potassium and 0.5% silk, the roots of order I of ramification were longer, especially in 0.5% tellura-M (4.7±0.4 cm), 1% humat potassium (4.5±0.2 cm), 0.5% phoenix (4.5±0.3 cm), 1% silk (4.5±0.5 cm) and 1% tellura-M (4.4±0.3 cm). The reliability of the difference between average values of these variants and control was substantial at 0.1% level of significance - for the first variant - $t_p = 4.2$ and $t_{th} = 3.4$, for the second one -$t_p = 6.1$ and $t_{th} = 3.3$, for the third one - $t_p = 4,7$ and $t_{th} = 3.4$, for the fifth one - $t_p = 4.4$ and $t_{th} = 3.4$; at 0.5% level of significance - for 1% silk ($t_p = 3.1$ and $t_{th} = 2.6$) and at 5% level of significance - for 1% phoenix ($t_p = 2.2$ and $t_{th} = 2.0$).

In comparison with control (0.9±0.1 cm) the longer roots of order II of ramification were marked in the variants of 0.5% phoenix (1.4±0.1 cm), 0.5% tellura-M (1.3±0.1 cm), 1% silk (1.2±0.1 cm) and 1% humat potassium (1.2±0.1 cm). The difference between average values of root length of order II in variants and control was significant for 0.5% phoenix, at 0.1% level of significance ($t_p = 3.5$ and $t_{th} = 3.3$), for 0.5% tellura-M, at 1% level of significance ($t_p = 2.9$ and $t_{th} = 2.6$), and for 1% humat potassium and 1% silk, at 5% level of significance ($t_p = 2.1$ and $t_{th} = 2.0$).

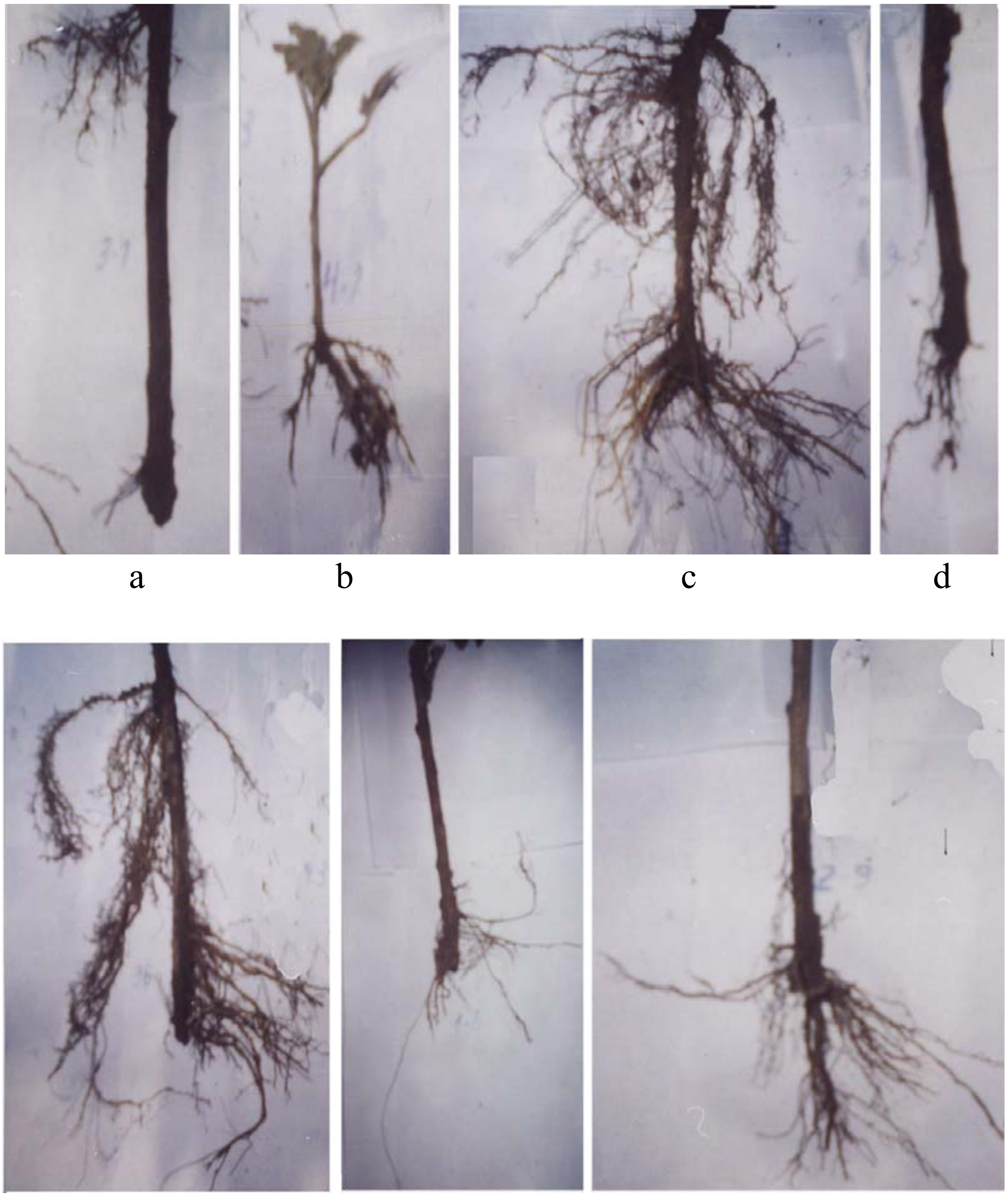

Fig. 1. Peculiarities of formation of rooting system of *Ribes atropurpureum* hardwood cuttings after treatment with growth regulators: a - control, H_2O, b – 0.5% humat potassium, c - 1% humat potassium, d - 1% silk; e – 0.5% tellura-bio; f – 0.5% phoenix; g - 1% phoenix.

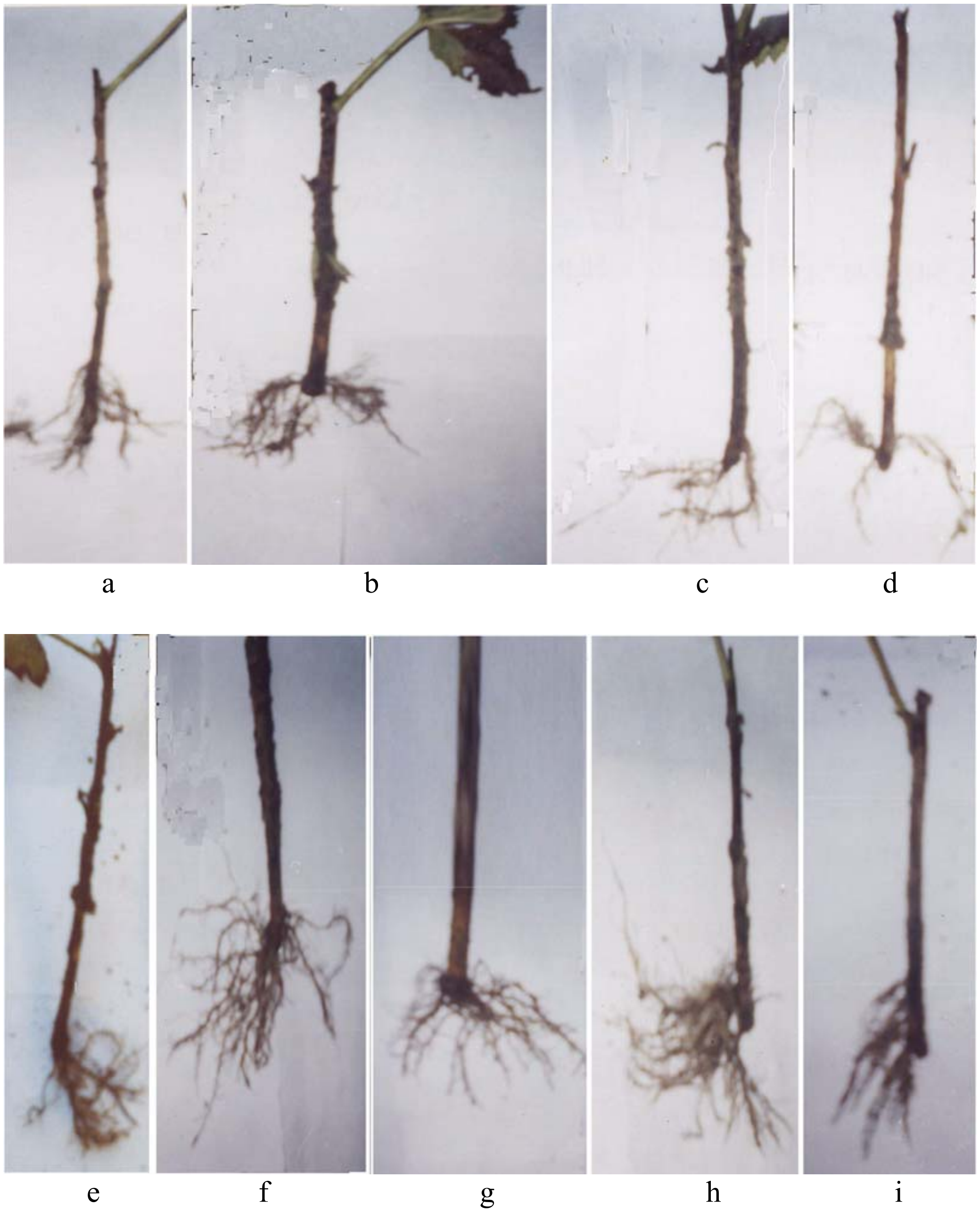

Fig. 2. Peculiarities of formation of rooting system of *Ribes atropurpureum* softwood cuttings after treatment with growth regulators: a - control, H_2O, b - 0,5% humat potassium, c - 1% humat potassium, d – 0.5% silk, e - 1% silk; f – 0.5% tellura-bio; g - 1% tellura-bio, h – 0.5% phoenix; i - 1% phoenix.

Table 2. Length of roots in *Ribes atropurpureum* hard-wood cuttings under the action of growth regulators, 2005.

Variant	Root length of different orders of ramification in a variant, cm					
	I order		II order		III order	
	n	$\frac{M \pm m}{\lim}$	n	$\frac{M \pm m}{\lim}$	n	$\frac{M \pm m}{\lim}$
Control, H_2O	14	$\frac{4,4 \pm 0,5}{2,0 - 8,0}$	28	$\frac{2,0 \pm 0,4}{0,5 - 10,0}$	4	$\frac{0,8 \pm 0,1}{0,5 - 1,0}$
Humat potassium, 0.5%	5	$\frac{4,9 \pm 0,6}{4,0 - 7,0}$	9	$\frac{3,0 \pm 0,8}{0,5 - 6,5}$	0	0
Humat potassium, 1%	19	$\frac{10,8 \pm 0,7}{4,0 - 15,0}$	295	$\frac{0,6 \pm 0,04}{0,3 - 5,0}$	96	$\frac{0,4 \pm 0,01}{0,3 - 0,5}$
Silk, 1%	3	$\frac{6,3 \pm 1,2}{4,0 - 8,0}$	4	$\frac{3,0 \pm 0,4}{2,2 - 4,0}$	31	$\frac{0,6 \pm 0,01}{0,5 - 0,7}$
Tellura-M, 0.5%	35	$\frac{10,5 \pm 0,7}{3,5 - 27,0}$	306	$\frac{0,9 \pm 0,1}{0,2 - 16,0}$	21	$\frac{0,6 \pm 0,1}{0,2 - 0,9}$
Phoenix, 0.5%	20	$\frac{8,5 \pm 0,9}{2,5 - 17,5}$	27	$\frac{3,3 \pm 0,8}{0,1 - 15,0}$	300	$\frac{0,7 \pm 0,02}{0,3 - 1,0}$
Phoenix, 1%	14	$\frac{7,7 \pm 0,6}{5,0 - 14,0}$	13	$\frac{3,4 \pm 0,5}{0,9 - 7,0}$	22	$\frac{0,4 \pm 0,03}{0,2 - 0,8}$

Longer roots of order III of ramification were in the variants of 1% humat potassium and 1% silk (by 0.9±0.1 cm, in control – 0.5±0.1 cm). The difference between average values of root length in these variants and control was substantial at 1% level of significance ($t_p = 2.9$ and $t_{th} = 2.6$).

As it is known, humat sodium is most commonly used among growth regulators for rooting cuttings of woody plants. We have not found any information on using humat potassium, tellura-M, phoenix and silk for these purposes. But an increase of root mass in air-dry state was noted when using 0,1% phoenix, 0,1% tellura-bio and 0,005% silk in growing strawberry seedlings (Lutov at al., 2003).

Table 3. Rooting ability of *Ribes atropurpureum* soft-wood cuttings after pre-planting treatment with growth regulators, 2005.

Variant	Rooting ability	
	piece	%
Control, H_2O	$\frac{4,0 \pm 0,8}{2-6}$	$\frac{16,0 \pm 3,2}{8,0-24,0}$
Humat potassium, 0.5%	$\frac{5,3 \pm 0,9}{3-7}$	$\frac{21,2 \pm 3,6}{12,0-28,0}$
Humat potassium, 1%	$\frac{3,0 \pm 0,7}{1-4}$	$\frac{12,0 \pm 2,8}{4,0-16,0}$
Silk, 0.5%	$\frac{2,8 \pm 1,3}{0-6}$	$\frac{11,2 \pm 5,2}{0,0-24,0}$
Silk, 1%	$\frac{2,0 \pm 0,7}{1-4}$	$\frac{8,0 \pm 2,8}{4,0-16,0}$
Tellura-M, 0.5%	$\frac{4,3 \pm 0,3}{4-5}$	$\frac{17,2 \pm 1,2}{16,0-20,0}0$
Tellura-M, 1%	$\frac{4,8 \pm 1,4}{1-7}$	$\frac{19,2 \pm 5,6}{4,0-28,0}$
Phoenix, 0.5%	$\frac{5,0 \pm 1,9}{0-9}$	$\frac{20,0 \pm 7,6}{0,0-36,0}$
Phoenix, 1%	$\frac{1,8 \pm 0,5}{1-3}$	$\frac{7,2 \pm 2,0}{4,0-12,0}$

Table 4. Formation of a root system in *Ribes atropurpureum* soft-wood cuttings under the action of growth regulators, 2005.

Variant	Number of rooted	Number of roots of different orders of ramification in one cutting, cm				
		I order *	II order	III order	IV order	V order
Control, H_2O	16	$\frac{5{,}6 \pm 1{,}1}{1-17}$	$\frac{15{,}8 \pm 3{,}4}{2-35}$	$\frac{9{,}0 \pm 2{,}8}{3-22}$	3	0
Humat potassium, 0.5%	21	$\frac{5{,}8 \pm 0{,}9}{1-13}$	$\frac{26{,}3 \pm 5{,}5}{2-77}$	$\frac{10{,}0 \pm 1{,}7}{3-23}$	$\frac{5{,}8 \pm 1{,}1}{3-8}$	0
Humat potassium, 1%	12	$\frac{3{,}8 \pm 0{,}6}{1-7}$	$\frac{11{,}6 \pm 3{,}2}{4-30}$	$\frac{11{,}3 \pm 6{,}4}{4-24}$	5	0
Silk, 0.5%	11	$\frac{4{,}3 \pm 0{,}8}{1-12}$	$\frac{11{,}3 \pm 2{,}3}{2-24}$	$\frac{6{,}0 \pm 1{,}2}{4-9}$	5	0
Silk, 1%	8	$\frac{6{,}7 \pm 1{,}6}{1-14}$	$\frac{19{,}6 \pm 6{,}8}{4-51}$	$\frac{7{,}9 \pm 2{,}0}{5-18}$	$\frac{5{,}0 \pm 0{,}6}{5-6}$	0
Tellura-bio, 0.5%	17	$\frac{6{,}0 \pm 0{,}7}{1-11}$	$\frac{17{,}8 \pm 4{,}1}{2-56}$	$\frac{7{,}8 \pm 2{,}0}{3-15}$	4	0
Tellura-bio, 1%	19	$\frac{4{,}5 \pm 1{,}0}{1-13}$	$\frac{11{,}3 \pm 2{,}6}{1-37}$	$\frac{5{,}1 \pm 0{,}9}{3-8}$	$\frac{4{,}0 \pm 1{,}0}{3-5}$	4
Phoenix, 0.5%	20	$\frac{4{,}3 \pm 0{,}7}{1-11}$	$\frac{10{,}3 \pm 1{,}7}{1-23}$	$\frac{6{,}9 \pm 0{,}8}{4-10}$	0	0
Control, H_2O	7	$\frac{4{,}5 \pm 0{,}9}{1-8}$	$\frac{7{,}0 \pm 1{,}8}{2-12}$	5	0	0

Table 5. Length of roots in *Ribes atropurpureum* soft-wood cuttings under the action of growth regulators, 2005.

Variant	Root length of different orders of ramification in a variant, cm									
	I order		II order		III order		IV order		V order	
	n	$\frac{M \pm m}{\lim}$	n	$\frac{M \pm m}{\lim}$	n	$\frac{M \pm m}{\lim}$	n	$\frac{M \pm m}{\lim}$	n	$\frac{M \pm m}{\lim}$
Control, H_2O	84	$\frac{2,8 \pm 0,2}{0,3-9,0}$	190	$\frac{0,9 \pm 0,1}{0,1-9,3}$	54	$\frac{0,5 \pm 0,1}{0,1-3,5}$	3	$\frac{0,3 \pm 0,1}{0,1-0,4}$	0	0
Humat potassium, 0.5%	99	$\frac{4,5 \pm 0,2}{1,0-13,4}$	374	$\frac{1,1 \pm 0,05}{0,1-6,5}$	79	$\frac{0,6 \pm 0,04}{0,1-3,0}$	4	$\frac{0,3 \pm 0,04}{0,1-0,9}$	0	0
Humat potassium, 1%	38	$\frac{2,7 \pm 0,3}{0,4-7,5}$	104	$\frac{1,2 \pm 0,1}{0,2-6,5}$	34	$\frac{0,9 \pm 0,1}{0,1-2,6}$	5	$\frac{0,3 \pm 0,03}{0,2-0,4}$	0	0
Silk, 0.5%	51	$\frac{3,2 \pm 0,2}{1,0-9,5}$	127	$\frac{1,1 \pm 0,1}{0,2-4,3}$	24	$\frac{0,5 \pm 0,1}{0,1-1,6}$	5	$\frac{0,1 \pm 0,02}{0,1-0,2}$	0	0

Continued

Silk, 1%	47	$\frac{4,5 \pm 0,5}{0,5 - 17,1}$	131	$\frac{1,2 \pm 0,1}{0,2 - 5,0}$	41	$\frac{0,9 \pm 0,1}{0,2 - 3,0}$	11	$\frac{0,3 \pm 0,04}{0,1 - 0,5}$	0	0
Tellura-bio, 0.5%	91	$\frac{4,7 \pm 0,4}{0,3 - 24,0}$	174	$\frac{1,3 \pm 0,1}{0,1 - 5,4}$	53	$\frac{0,4 \pm 0,05}{0,1 - 2,0}$	4	$\frac{0,2 \pm 0,05}{0,1 - 0,3}$	0	0
Tellura-bio, 1%	71	$\frac{4,4 \pm 0,3}{0,4 - 13,8}$	169	$\frac{1,1 \pm 0,1}{0,2 - 4,5}$	36	$\frac{0,6 \pm 0,1}{0,2 - 2,6}$	8	$\frac{0,7 \pm 0,2}{0,3 - 1,6}$	4	$\frac{0,1 \pm 0,03}{0,1 - 0,2}$
Phoenix, 0.5%	64	$\frac{4,5 \pm 0,3}{0,5 - 12,3}$	155	$\frac{1,4 \pm 0,1}{0,1 - 8,0}$	55	$\frac{0,5 \pm 0,04}{0,2 - 1,3}$	0	0	0	0
Control, H_2O	27	$\frac{4,0 \pm 0,5}{0,5 - 9,3}$	35	$\frac{1,0 \pm 0,1}{0,3 - 3,0}$	5	$\frac{0,5 \pm 0,1}{0,3 - 0,6}$	0	0	0	0

CONCLUSIONS

1. *R. atropurpureum* belongs to hard-to-root plants; the rooting ability of soft-wood plants is greater than that of hard-wood.

2. Humat potassium, tellura-M and phoenix are promising growth regulators for rooting *R. atropurpureum* cuttings. The best variants for rooting were 0.5% tellura-M for hard-wood cuttings and 0.5% humat potassium for soft-wood ones.

3. In hard-wood cuttings the roots of orders I–III of ramification are mainly formed in lower, in lower and upper and in upper nodes. More roots are formed under the action of 1% humat potassium, 0.5% tellura-M and 0.5% phoenix. The longest roots of order I are formed in these variants.

4. More roots are formed in soft-wood cuttings under the action of 0.5 and 1% humat potassium, 0.5 and 1% tellura-M and 0.5% phoenix. The longest roots of order I of ramification are formed in 0.5% tellura-M, 0.5% humat potassium, 0.5% phoenix and 1% silk.

5. In hard-wood cuttings the roots of orders I and II of ramification are longer than those in soft-wood ones, but their branching is poorer.

There is need for additional study of the influence of both currently used and new growth regulators on the root formation of hard-wood, soft-wood and combined cuttings of *R. atropurpureum* that may show promise for further development of methods of vegetative propagation.

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