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Стимулирование корнеобразования при черенковании винограда сортов Виктория и Коринка русская действием калиевой соли индол-3-уксусной кислоты

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РЕЗЮМЕ

Актуальность. Использование экзогенных ауксинов для улучшения корнеобразования у черенков винограда является широко распространенным приемом. По литературным данным, препараты калиевых солей, используемые этих для этих целей, могут давать как положительный, так и отрицательный эффекты, либо эффект вообще может отсутствовать, поскольку эффект стимулирования корнеобразования зависит от генетических особенностей растения, типа и концентрации ауксина и многих других факторов.

Материал и методы. Целью настоящей работы была оценка эффективности использования калиевой соли индолил-3-уксусной кислоты (KIAA) на корнеобразование черенков двух сортов винограда: Коринка русская и Виктория, выращиваемых в Татарстане. Исследование проводили в 2018-2019 годах в условиях гидропоники в растильных камерах Казанского аграрного университета. Черенки обрабатывали: 1) KIAA в двух концентрациях (5,000 и 10,000 мг/л; 2) β-индолил-бутировая кислота (IBA) 3,000 мг/л (в качестве сравнения) и 3) дистиллированная вода (контроль).

Результаты. Показано, что KIAA значительно улучшает корнеобразование обоих сортов. Процент корнеобразования, среднее количество корней в расчете на один черенок, а также качество корневой системы повышалось с возрастанием концентрации ауксина вплоть до 10.000 мг/л. IBA также повышала процент корнеобразования и показатели качества по сравнению с контролем. Исследуемые сорта сильно различались по способности корнеобразования: черенки Коринки русской как в 2018, так и в 2019 годах характеризовались более высокими показателями корнеобразования и их качества по сравнению с сортом Виктория. Исключение составлял показатель «процент каллусообразования», который оказался выше у сорта Виктория.

Ключевые слова: черенки, сорта винограда, корнеобразование, регуляторы роста растений, калиевая соль ауксина, обработки

Rooting stimulation of "Victoria" and "Korinka russkaya" grape hardwood cuttings as influenced by potassium salt of Indolyl-3-Acetic Acid (KIAA)

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ABSTRACT

Relevance. Applying exogenous auxins to the cuttings of grapevines is a common practice in viticulture to improve the rooting process. The potassium salt formulations of auxins have been documented to be more, less, or equally efficient as acid formulations in rooting stimulation of cuttings depending on the genetic features of the plant, type and concentration of auxin, type of cuttings, and many other factors.

Methods. The present study aimed at evaluating the effect of potassium salt of indolyl-3-acetic acid (KIAA) on rooting of the hardwood cuttings of two grape cultivars namely, Korinka russkaya and Victoria, which are commonly planted by grape growers of the Tatarstan Republic. The study was conducted in 2018 and 2019 under hydroponic conditions in a controlled-environment growth chamber in Kazan State Agrarian University. The cuttings were treated with 1) KIAA at two concentrations (5,000 and 10,000) ppm; 2) β-indolyl-butyric acid (IBA) 3,000 ppm (as a check treatment) and 3) distilled water as a control.

Results. Based upon the overall results, KIAA significantly improved the rooting process of both investigated cultivars. Rooting percentage, average number of roots on cuttings as well as the quality of the root system was enhanced with increasing auxin concentration up to 10,000 ppm. IBA also improved the rooting quality parameters over the controls. The two grape cultivars differed significantly in their rooting capacity: cuttings of Korinka russkaya in both years had greater values of all the studied parameters compared with those of Victoria cultivar except for the callusing percentage, which was higher in Victoria.

Keywords: hardwood cuttings, grape cultivars, rooting, plant growth regulators, potassium salt of auxins, treatment.

INTRODUCTION

Rooting of hardwood cuttings is one of the most effective and common techniques for grape clonal propagation. Many different practices for stimulation of grape cuttings rooting have been tried with different success levels during the course of grape growing. Utilization of plant growth regulators, especially auxins, has been one of the most viable practices for this purpose [1, 2]. The findings that root formation in cuttings is promoted by auxin, and the accessibility to synthetic auxins since 1930s [3], have triggered a massive amount of work on the application of this technique for improving propagation practices.

Auxin treatments are applied to improve the rooting percentage, increase the number and length of roots, and enhance the quality of root system [4,5]. Indole-3-acetic acid (IAA), indole-3-butyric acid (IBA) and 1-naphthaleneacetic acid (NAA) as well as their potassium (K) salts were shown to be the most commonly used auxins for root stimulation and development on cuttings, with the IBA coming on the top of this list, reviewed by Blythe et al., 2007 [6].

Several studies have documented the effect of the exogenously applied auxins on stimulating, inhibiting or generally regulating rooting of grape cuttings. In their investigations to assess the usefulness of IBA application to the cuttings of some grape varieties and rootstocks, Daskalakis et al., 2018 [7]; Doğan et al.,2016 [8]; Galavi et al., 2013 [9] documented that IBA treatments at specific concentrations improved rooting percentage, number of roots on cuttings, and root length. On the contrary, other studies showed that exogenous auxins can have no significant improvement or even inhibit the rooting process of grape cuttings [10, 11, 12].

The potassium salt (K-salt) formulations of auxins (e.g., KIBA, KIAA and KNAA) enable these auxins to be dissolved in water with no organic solvents needed. They have been documented to be more, less, or equally efficient as acid formulations in rooting stimulation of cuttings depending on the genetic features of the plant, type and concentration of auxin, type of cutting, and many other factors [13, 14, 15, 16].

Treatment of Norton (*Vitis aestivalis*) grape hardwood cuttings with 10,000 or 15,000 ppm KIBA induced more than 70% of the cuttings to root, in contrast to 23% rooting of the non-treated cuttings [17]. In a previous experiment, the hardwood cuttings of the same variety were treated with (0; 2,500; 5,000; 7,500 and 10,000) ppm of KNAA or KIBA. Cuttings responded similarly to both auxins showing no significant improvement in rooting percentage or root length. Nevertheless, number of roots per cutting was significantly influenced as cuttings treated with 10,000 ppm auxins gave 4 times more roots than the non-treated controls [18].

Potassium was proved to have a remarkable effect on rooting process of plants through regulating carbohydrate metabolism. Amtmann and Armengaud, 2009 [19] reported that efficient K concentration is associated with the activation of enzymes like pyruvate kinase, glucokinase and fructokinase which are responsible for carbohydrate metabolism in plants. They also documented that K deficiency reduced significantly both root sugar and pyruvate kinase concentrations. In their study on hardwood cuttings of eastern redcedar (*Juniperus virginiana* L.) Henry et al., 1992 [20] found that rooting percentage and root length significantly correlated with starch and sucrose concentrations, respectively. Out of the mineral nutrients analyzed in this experiment (N, P, K, Ca, Mg, Mn, and B), only B and K were significantly associated with the rooting ability of cuttings.

Another way of K influencing rooting process of plants is via endogenous auxin management. Zhi-yong et al., 2009 [21] found that K deficiency in cotton seedlings significantly inhibited root length and the ability to form lateral roots. In addition, the endogenous free IAA content was reduced by 50%, in the roots grown in K deficient media. In another study, potassium chloride (KCl) significantly induced rooting of cucumber cotyledons and when added to IAA, it has an additional induced rooting effect. Several salts of potassium also induced significantly the rooting process of cucumber cotyledons [22]. In addition, Vicente-Agullo et al., 2004 [23] reported that the K carrier TRH1 is essential for auxin transport in Arabidopsis roots.

The objectives of this research were: first, to evaluate the effect of KIAA as a source of both K and IAA on the rooting process of grape hardwood cuttings compared with the prevalently used auxin in the nursery sector (IBA) since it was used as a check treatment in our study. Second, to evaluate the cultivar effect on the rooting ability of cuttings as we investigated on two different cultivars (Korinka russkaya and Victoria).

MATERIALS AND METHODS

The plant materials (canes) in this study originated from vines of the Russian grape cultivars Korinka russkaya and Victoria that were growing in the educational garden of Kazan State Agrarian University. They represent some of the most widely used cultivars by grape growers and gardeners in the open fields of the Tatarstan Republic. These cultivars are characterized by sufficiently high and stable yields as well as high quality grapes. The study was conducted during two consecutive years, 2018 and 2019 but results in this article are presented as a one group of data because of the similarity in results of both years.

One-year old wood canes were collected from vines of healthy and normal vigor of the desired cultivars during the autumn pruning of vines (in November). The canes were stored in plastic bags at a temperature of 2…4°C. At the end of March, canes were soaked in tap water at room temperature for 24 hours, the canes were then cut into two or three eyes cuttings of almost similar length and diameter. Cuttings were aligned and their basal ends (5–6 cm) were dipped for 10 seconds in the following: a) distilled water (control); b) solution of 3000 ppm IBA; c) solution of 5000 ppm KIAA; solution of 10000 ppm KIAA. The experiment involved 4 replications per treatment with 10 cuttings in each replication. All cuttings were labeled and numbered. The experiment was set in a completely randomized design.

Cuttings were placed to root under hydroponic conditions in a laboratory or, more specifically, in a controlled-climate growth chamber at temperature of 24±2єC, 70±5% relative humidity and a light intensity of 12.000 lux in a photoperiod of 16 hours per day. The water layer was maintained at the level of 5-6 cm throughout the entire experiment. Growth conditions, employing water as the culture media for grape cuttings, were maintained as explained by Radchevsky, 2014 [24], Daskalakis et al., 2018 [7], Sabir and Sabir, 2018 [25].

Measurements took place after 60 days of starting the experiment. Bud burst, callusing and rooting percentages were obtained through calculating how many of the cuttings in every group of ten per replicate that gave open eyes, formed callus and gave at least one root, respectively. Those numbers were recorded as percentages. Number of roots on every cutting was also counted to get the average root number. The length of roots (including root branches) was counted to calculate the average length of roots.

The significance of the differences among results was examined through means of two-way analysis of Variance (ANOVA), where the effect of the two investigated factors (cultivar and auxin treatment) was evaluated. One-way ANOVA test was then used to check the effect of auxin treatment for each cultivar separately. When significant effect detected, the means of the treatments were separated using the Duncan's Post-Hoc test. Data analysis was performed using CoStat statistical software, version 6.45 (CoStat 2005) and p-value ≤ 0.05 was considered to be significant.

RESULTS AND DESCUSSION

1. Bud burst (%)

Results of the two-way ANOVA test presented in Table 1 cleared that cultivar and auxin treatment significantly influenced bud burst (%), but interaction between these two factors had no effect on this parameter. Cuttings of Korinka russkaya had significantly higher bud burst percentage (23.9% higher) than Victoria (Table 2). As shown by the results of one-way ANOVA (Table 3), both IBA and

Table 1. Results of the Two-way ANOVA test evaluating effects of Cultivar (A) and auxin treatment (B) on rooting properties of the investigated grape cuttings

	Bud burst (%)	Callusing (%)	Rooting (%)	Mean root number	Mean root length (cm)
Culivar (A)	***	***	***	***	***
Treatment (B)	**	***	**	***	***
A*B	ns	ns	ns	**	ns

*ns, not significant effect, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.*

Table 2. Mean values of rooting properties of grape cuttings according to cultivar and auxin treatments

Cultivar	Treatment	Bud burst (%)	Callusing (%)	Rooting (%)	Mean root number	Mean root length (cm)
Korinka russkaya	Control	75.0 b	7.5 c	72.5 c	12.7 b	71.2 c
	IBA 3,000 ppm	87.5 a	35.0 a	82.5 ab	22.4 a	113.3 b
	KIAA 5,000 ppm	85.0 ab	7.5 c	77.5 bc	21.3 a	101.9 b
	KIAA 10,000 ppm	92.5 a	22.5 b	90.0 a	21.4 a	140.1 a
	Mean	**86.0 a***	**18.7 b***	**81.3 a***	**19.9 a***	**109.1 a***
Victoria	Control	50.0 c	18.8 b	43.0 b	6.3 c	16.3 d
	IBA 3,000 ppm	65.0 ab	40.5 a	53.8 b	16.7 b	35.2 c
	KIAA 5,000 ppm	56.3 bc	16.7 b	53.8 b	13.7 b	49.2 b
	KIAA 10,000 ppm	75.0 a	43.8 a	68.8 a	23.9 a	68.3 a
	Mean	**62.1 b***	**30 a***	**55.9 b***	**15.0 b***	**43.8 b***

Means within the same column and same cultivar with different letters (a–c) are significantly different at the $p \leq 0.05$ level according to Duncan's Post Hoc-test.

Table 3. Results of the one-way ANOVA test evaluating effects of Auxin treatments rooting properties of every cultivar separately

	Bud burst (%)	Callusing (%)	Rooting (%)	Mean root number	Mean root length (cm)
Karinka rosskaia	*	***	**	***	***
Victoria	**	***	**	***	***

*ns, not significant effect, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.*

KIAA had increased bud burst percentage of the two cultivars over the controls, however the Post-Hoc-test revealed that this increase was not significant for both cultivars treated with KIAA 5,000 mg/l (Table 2). The positive effect of auxin on bud burst% of Augustin grape cuttings was also documented by Radchevsky et al., 2012 [26].

2. Callusing (%)

On the basis of one-way and two-way ANOVA results, both cultivar and auxin treatment significantly affected callus formation (Table 1, 3). The higher callusing (%) was observed in cuttings of Victoria cultivar (almost twice the number of callusing% in cuttings of Korinka russkaya) (Table 2). KIAA 10,000 ppm and IBA 3,000 ppm gave a significantly higher callusing% than the controls of both cultivars (Table 2). Similarly, Daskalakis et al., 2018 [7] also found that a higher concentration of IBA significantly increased callusing% of grape cuttings compared to the lower concentration and the control. In contrast, Sims, 2011 [19] studying the effect of KIBA on rooting process of kiwifruit (Actinidia chinensis) cultivar "AU Golden Sunshine" reported that the callus size was significantly larger for the control, 1,000 ppm and 2,500 ppm KIBA versus the callus size of the high auxin concentration treatments (5,000 ppm and 10,000 ppm).

3. Rooting (%)

Results of the Two-way ANOVA test (Table 1) showed that cultivar and auxin treatments had significant effect on rooting (%) of grape cuttings. As presented in Table 2, cuttings of Korinka russkaya had significantly higher rooting percentage (25.4% higher) than those of Victoria. Auxin treatment significantly improved rooting% of the cuttings compared with the non-treated ones (Table 3). The highest results within each cultivar were observed in cuttings treated with KIAA 10,000 ppm (Table 2). Similar findings were observed by Keeley et al., 2004 [17] who reported that treatment of Norton (*Vitis aestivalis*) grape cuttings with 10,000 or 15,000 ppm KIBA induced more than 70% of the cuttings to root, compared with 23% rooting of the non-treated ones.

Potassium was proved to have a significant effect on root sugar and pyruvate kinase concentrations in plants affecting the carbohydrate metabolism process and consequently, affecting roots formation and development [19]. Carbohydrate concentrations within cuttings were documented to be highly associated with rooting ability [20, 27, 28]. Henry et al., 1996 [20] also added that, only B and K among the mineral nutrients analyzed (N, P, K, Ca, Mg, Mn, and B), were significantly correlated with rooting ability of hardwood cuttings of eastern red cedar (*Juniperus virginiana* L.).

a. Roots number per cutting

As shown in Tables 2,3, Auxin treatment significantly increased roots number on cuttings of both cultivars over the nontreated ones. Cuttings of Korinka russkaya gave higher average number of roots (4.9 more roots) over Victoria. The Two-way ANOVA test proved this significant influence of cultivar and auxin treatments (Table 1). It also showed a significant interaction between these two factors where KIAA 10,000 had the highest increase in roots number of Victoria (4 times more roots than the control), followed by both KIAA 5,000 ppm and IBA 3,000 ppm (almost 2 times more roots over the control). Nevertheless, there was no significant difference among these three auxin treatments in cuttings of Korinka russkaya with all of them giving number of roots significantly higher than the control (almost 2 times higher). This confirms the results found by Keeley et al., 2003 [18] and Radchevsky et al., 2012 [26] using potassium salt of auxins on grape cuttings. Doğan et al. 2016 [8] and Galavi et al. 2013 [9] also found the highest increase in number of roots of grape cuttings treated with 4,000 ppm IBA.

b. Mean root length (cm)

The results of ANOVA tests as listed in tables 1,3 cleared a highly significant effect of cultivar and auxin treatment on the mean root length on cuttings. Mean root length of Korinka russkaya twice exceeded that of Victoria. The highest root length was found on cuttings treated with KIAA 10,000 ppm for both cultivars. For Victoria, KIAA 5,000 ppm came as second-best treatment followed by IBA then lastly came the non-treated controls. Differently, for Korinka russkaya both KIAA 5,000 ppm and IBA appeared as second-best (with no significant difference between them) then the non-treated controls (Table 2). The importance of K for root elongation was proved by Zhi-Yong et al., 2009 [21] who found that K deficient treatment on cotton seedlings significantly inhibited root length and the formation of lateral roots. The reason of such inhibition was that the endogenous free IAA content reduced by 50% in the roots grown in K deficient media. Vicente-Agullo et al., 2004 [23] also reported that the K carrier TRH1 is required for auxin transport in Arabidopsis roots.

4. CONCLUSION

Based on these results, it appears that KIAA significantly improved the rooting process of both investigated cultivars. Rooting (%), number of roots on cuttings as well as the quality of the root system were enhanced with increasing auxin concentration up to 10,000 ppm. IBA 3,000 ppm also improved the rooting properties over the controls. The two grape cultivars differed significantly in their rooting capacity, cuttings of Korinka russkaya had greater values of all the studied parameters compared with those of Victoria except for the callusing (%) which was higher in Victoria.

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Литература / References

[1] Alley, C. Propagation of grapevines. *California Agriculture Journal.* 1980;(7):29–30.
[2] Smith B., Waite H., Dry N. and Nitschke D. Grapevine propagation best practices, part 2. *Wine and Viticulture Journal.* 2012;(7):49-51.
[3] Thimann, K.V. and Koepfli, J.B. Identity of the growth-promoting and root-forming substances of plants. *Nature.* 1935;(135):101–102.
[4] Pop, T.I., Pamfil, D. and Bellini, C. Auxin control in the formation of adventitious roots. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca.* 2011;39(1):307–316.
[5] Pacurar, D. I., Perrone, I. and Bellini, C. Auxin is a central player in the hormone cross-talks that control adventitious rooting. *Physiologia Plantarum.* 2014;151(1):83–96.
[6] Blythe E.K., Sibley J.L., Tilt K.M. and Ruter J.M. Methods of auxin application in cutting propagation: A review of 70 years of scientific discovery and commercial practice. *Journal of Environmental Horticulture.* 2007;25(3):166-185.
[7] Daskalakis, I., Biniari, K., Bouza, D. and Stavrakaki, M. The effect that indolebutyric acid (IBA) and position of cane segment have on the rooting of cuttings from grapevine rootstocks and from Cabernet franc (*Vitis vinifera* L.) under conditions of a hydroponic culture system. *Scientia Horticuturae.* 2018;(227):79–84.
[8] Doğan, A., Cьneyt, U. and Kazankaya, A. Effects of Indole-Butyric Acid Doses, Different Rooting Media and Cutting Thicknesses on Rooting Ratios and Root Qualities of 41B, 5 BB and 420A American Grapevine Rootstocks. *Journal of Applied Biological Sciences.* 2016;10(2):8–15.
[9] Galavi, M., Karimian, M.A. and Mousavi, S.R. Effects of Different Auxin (IBA) Concentrations and Planting-Beds on Rooting Grape Cuttings (*Vitis vinifera*). *Annual Review & Research in Biology.* 2013;3(4):517–523.
[10] Alley, C.J., Factors Affecting The Rooting of Grape Cuttings. II. Growth Regulators. *American Journal of Enology and Viticulture.* 1961;(12):185-190.
[11] Castro, P.R.C., Melotto E. and Soares, F.C. Rooting Stimulation in Muscadine Grape Cuttings. *Scientia Agricola.* 1996;51(3):436–440.
[12] Kracke, H. and Cristoferi, G. Effect of IBA And NAA Treatments on the Endogenous Hormones in Grapevine Rootstock Hardwood Cuttings. *Acta Horticulturae.* 1983;(137):95–102.
[13] Bielenin, M. Rooting and Gas Exchange of Conifer Cuttings Treated with Indolebutyric Acid. *Journal of Fruit and Ornamental Plant Research.* 2003;(11):99–105.
[14] Van Bragt, J., Van Gelder, H. and Pierik, R.L.M.. Rooting of Shoot Cuttings of Ornamental Shrubs after Immersion in Auxin-Containing Solutions. *Scientia Horticulturae.* 1976;4(1):91–94.
[15] Blythe, E.K., Sibley, J.L., Tilt, K.M. and John, M.R. "Rooting of Rose Cuttings in Response to Foliar Applications of Auxin and Surfactant. *HortTechnology*. 2004;14(4):479–483.
[16] Sims, B.J., Rooting Evaluation of Kiwifruit (*Actinidia chinensis*) and Effects of Anaerobiosis on Bud Break. Thesis, Alabama, U.S.A. 2011. 43 p.
[17] Keeley, K., Preece, J.E., Taylor, B.H. and Dami, I.E. Effects of High Auxin Concentrations, Cold Storage, and Cane Position on Improved Rooting of Vitis Aestivalis Michx. Norton Cuttings. *American Journal of Enology and Viticulture.* 2004;55(3):265–268.
[18] Keeley, K., Preece, J.E. and Taylor, B.H. Increased Rooting of 'Norton' Grape Cuttings Using Auxins and Gibberellin Biosynthesis Inhibitors. *HortScience*. 2003;38(2):281–283.
[19] Amtmann, A. and Armengaud, P., Effects of N, P, K and S on Metabolism: New Knowledge Gained from Multi-Level Analysis. *Current Opinion in Plant Biology*. 2009;(12):275–283.
[20] Henry, P.H., Blazich, F.A. and Hinesley, L.E. Nitrogen Nutrition of Containerized Eastern Redcedar . II . Influence of Stock Plant Fertility on Adventitious Rooting of Stem Cuttings. *Journal of the American Society for Horticulture Science*. 1992;117(4):568–570.
[21] Zhi-yong, Z., Qing-lian, W., Zhao-hu, L., et al., Effects of Potassium Deficiency on Root Growth of Cotton Seedlings and Its Physiological Mechanisms. *Acta Agronomica Sinica.* 2009;35(4):718–723.
[22] Zhao, Z.R., Li, G.R.and Huang, G.Q. Promotive Effect of Potassium on Adventitious Root Formation in Some Plants. *Journal of Plant Science*. 1991;(79):47–50.
[23] Vicente-Agullo, F., Rigas, S., Desbrosses, G., et al. Potassium Carrier TRH1 Is Required for Auxin Transport in Arabidopsis Roots. *The Plant Journal*. 2004;(40):523–535.
[24] Radchivsky, P.P. "Rooting Ability of 5-eyed Cuttings of Resistant Grape Varieties When Rooted in Water. *Educational Journal of Kuban State Agrarian University.* 2014;(95):1–17. (in Russian)
[25] Sabir, F.K. and Sabir, A. Effects of Different Storage Conditions on Rooting and Shooting Performance of Grapevine (*Vitis vinifera* L.) Cuttings in Hydroponic Culture System. *International Journal of Sustainable Agricultural Research.* 2018;5(3):46–53.
[26] Radchivsky P.P., Kolko E.A., Ocibova D.C., Ocibova M.C. The Effect of Heteroauxin on the Regenerative Ability of Cuttings of Sustainable Table Grape Varieties Augustine and Moldova. In *Innovative Technologies and Trends in Development of Modern Viticulture and Wine-making,* Nikolsky, M.A., Ed., Anapa: Conf. Proceedings, 2012. 114-118 p. (in Russian).
[27] Bartolini, G., Pestelli, P., Toponi, M.A. and Di Monte, G. Rooting and Carbohydrate Availability in Vitis 140 Ruggeri Stem Cuttings. *Vitis.* 1996;35(1):11–14.
[28] Satisha, J. and Adsule, P.G. Rooting Behavior of Grape Rootstocks in Relation to IBA Concentration and Biochemical Constituents of Mother Vines. *Acta Horticulturae*. 2008;785(3):121–126.