PERIÓDICO TCHÊ QUÍMICA
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COMPOSTOS ORGÂNICOS SINTESIZADOS UTILIZADOS COMO ESTIMULANTES DE CRESCIMENTO PARA PLANTAS LENHOSAS

SYNTHESIZED ORGANIC COMPOUNDS AS GROWTH STIMULATORS FOR WOODY PLANTS

СИНТЕЗИРОВАННЫЕ ОРГАНИЧЕСКИЕ СОЕДИНЕНИЯ КАК СТИМУЛЯТОРЫ РОСТА ДЛЯ ДРЕВЕСНЫХ РАСТЕНИЙ

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RESUMO

Estudou-se o efeito de compostos orgânicos sintetizados de 6-hidroxi-2,2,4-trimetil-1,2-di-hidroquinolina, seus derivados e análogos hidrogenados sobre a altura de mudas de plantas lenhosas ornamentais. A altura das mudas como parâmetro morfométrico foi medida sete meses após o início do experimento. O tratamento pré-semeadura de *Rhododendron ledebourii* e *Rhododendron smirnowii*, com os compostos estudados, demonstrou que a di-hidro e a tetra-hidroquinolina com concentração de 0,1% foram os mais eficientes. As dihidroquinolinas nas concentrações de 0,05 e 0,1% demonstraram ter o efeito mais forte. As dihidroquinolinas para plantas lenhosas perenes são mais eficazes, depois as tetrahidroquinolinas. Os compostos químicos sintetizados mais eficientes para o *rododendro* contêm substituto de benzoíla. Para *Rh. ledebourii* e *Rh. smirnowii* os mais eficazes são os mesmos compostos químicos sintetizados: 6-hidroxi-2,2,4-trimetil-1,2,3,4-tetra-hidroquinolina, 6-hidroxi-2,2,4-trimetil-1,2-di-hidroquinolina e 1-benzoil-6-hidroxi-2,2,4-trimetil-1,2-di-hidroquinolina com concentrações de 0,01, 0,05 e 0,1%. Estes compostos, quando aplicados com o tratamento de *Rh ledebourii* e *Rh. smirnowii* antes da semeadura, resultam em um aumento na altura das mudas em 3,6-89,3% e 14,3-57,1%, respectivamente. O efeito de compostos químicos sintetizados de 6-hidroxi-2,2,4-trimetil-1,2-di-hidroquinolina e seu análogo hidrogenado em plantas lenhosas do mesmo gênero não é específico da espécie. Sugere-se o uso de compostos de 6-hidroxi-2,2,4-trimetil-1,2-di-hidroquinolina, seus derivados e análogos hidrogenados como estimuladores do crescimento do rododendro. Os compostos da série quinolina foram testados quanto à genotoxicidade pelo método citológico no objeto modelo (*Betula pendula*) e reconhecidos como ambientalmente amigáveis. As respostas citogenéticas para *Betula pendula* e *Rhododendron* são idênticas; portanto, os compostos positivos influenciam as células de *Betula pendula* devido ao aumento da atividade metabólica, o mesmo ocorre com o *rododendro*. Portanto, compostos orgânicos sintetizados podem ser recomendados como estimuladores de crescimento eficazes.

Palavras-chave: *estimuladores de crescimento, compostos orgânicos sintetizados, plantas lenhosas*.

ABSTRACT

The effect of synthesized organic compounds of 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline, its derivatives, and hydrogenated analogs on the height of seedlings of ornamental woody plants was studied. The height of seedlings as a morphometric parameter was measured 7 months after the start of the experiment. The pre-sowing seed treatment of *Rhododendron ledebourii* and *Rhododendron smirnowii*, with the studied compounds, demonstrated that dihydro- and tetrahydroquinoline with the concentration of 0.1% proved to be the most efficient. Dihydroquinolines at concentrations of 0.05 and 0.1% proved to have the strongest effect. Dihydroquinolines for perennial woody plants are more effective, then tetrahydroquinolines. The most efficient synthesized chemical compounds for *Rhododendron* contain benzoyl substitute. For *Rh. ledebourii* and *Rh. smirnowii* the most effective are the same synthesized chemical compounds: 6-hydroxy-2,2,4-trimethyl-1,2,3,4-tetrahydroquinoline, 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline, and 1-benzoyl-6-hydroxy-2,2,4-trimethyl-1,2-

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dihydroquinoline with concentrations of 0.01, 0.05, and 0.1%. These compounds, when applied with the pre-sowing seed treatment of *Rh. ledebourii* and *Rh. smirnowii*, result in an increase in the height of the seedlings by 3.6-89.3% and 14.3-57.1%, respectively. The effect of synthesized chemical compounds of 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline and its hydrogenated analog on woody plants of the same genus is not species-specific. It is suggested using the compounds of 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline, its derivatives, and hydrogenated analogs as growth stimulators for *Rhododendron*. The compounds of the quinoline series were tested for genotoxicity by the cytological method in the model object (*Betula pendula*) and recognized as environmentally friendly. The cytogenetic responses for *Betula pendula* and *Rhododendron* are identical, so positive compounds influence for *Betula pendula* cells because of increased metabolic activity means the same for *Rhododendron*. Therefore, synthesized organic compounds can be recommended as effective growth stimulators.

Keywords: *growth stimulators, synthesized organic compounds, woody plants*.

АННОТАЦИЯ

Исследовано влияние синтезированных органических соединений 6-гидрокси-2,2,4-триметил-1,2-дигидрохинолина, его производных и гидрированных аналогов на высоту проростков декоративных древесных растений. Высота сеянцев как морфометрический параметр измерялась через 7 месяцев после начала эксперимента. Предпосевная обработка семян *Rhododendron ledebourii* и *Rhododendron smirnowii* изученными соединениями показала, что дигидро- и тетрагидрохинолин с концентрацией 0,1% оказались наиболее эффективными. Дигидрохинолины в концентрациях 0,05 и 0,1% оказались наиболее сильными. Дигидрохинолины для многолетних древесных растений более эффективны, чем тетрагидрохинолины. Наиболее эффективные синтезированные химические соединения для рододендрона содержат бензоильный заменитель. Для *Rh. ledebourii* и *Rh. smirnowii* наиболее эффективными являются одни и те же синтезированные химические соединения: 6-гидрокси-2,2,4-триметил-1,2,3,4-тетрагидрохинолин, 6-гидрокси-2,2,4-триметил-1,2-дигидрохинолин и 1-бензоил-6-гидрокси-2,2,4-триметил-1,2-дигидрохинолин с концентрациями 0,01, 0,05 и 0,1%. Эти соединения, когда применяются при предпосевной обработке семян *Rh. ledebourii* и *Rh. smirnowii*, приводят к увеличению высоты сеянцев на 3,6-89,3% и 14,3-57,1% соответственно. Влияние синтезированных химических соединений 6-гидрокси-2,2,4-триметил-1,2-дигидрохинолина и его гидрированного аналога на древесные растения одного и того же рода не является видоспецифичным. Предлагается использовать соединения 6-гидрокси-2,2,4-триметил-1,2-дигидрохинолина, его производных и их гидрированных аналогов в качестве стимуляторов роста рододендрона. Соединения серии хинолинов были проверены на генотоксичность цитологическим методом на модельном объекте (*Betula pendula*) и признаны экологически чистыми. Цитогенетические ответы для *Betula pendula* и *Rhododendron* идентичны, поэтому положительное влияние соединений на клетки *Betula pendula* из-за повышенной метаболической активности означает то же самое для *Rhododendron*. Поэтому синтезированные органические соединения могут быть рекомендованы в качестве эффективных стимуляторов роста.

Ключевые слова: *стимуляторы роста, синтезированные органические соединения, древесные растения*

1. INTRODUCTION

The biological effect of quinolinic compounds (Abdel-Gawad *et al*., 2005; Shujiang *et al*., 2005; Williamson, Ward 2005; Denmark, Venkatraman, 2006; Shikhaliev *et al*., 2014; Ghoneim, Assy, 2015), such as dihydro- and tetrahydroquinoline, on seed germination and the root growth of the stem cuttings of woody plants, is currently being studied (Shmyreva, 2000; Butorina *et al*., 2002; Baranova, 2013a). Environmentally friendly quinolinic compounds (Dorey *et al*., 2000; Butorina *et al*., 2002; Abdel-Gawad *et al*., 2005; El-Gazzar *et al*., 2009; Baranova, 2013a) are widely used to produce planting material, which is then planted in anthropogenically polluted areas (Moiseeva *et al*., 2012a; Kalaev *et al*., 2013). It was demonstrated that depending on their concentrations, and quinolinic compounds have a different effect on seed germination and the height of the seedlings of the woody plants of *Rhododendron* L genus (Moiseeva *et al*., 201a; Kalaev *et al*., 2013). This means that the same quinolinic compounds at different concentrations may either stimulate or inhibit the biological processes (Dlugosz, Dus, 1996; Gavrilov et al., 1988; Litvinov, 1998; Dorey *et al*., 2000; El-Sayed et al., 2002a,b, 2004; Saudi *et al*., 2003; Brown *et al*., 2004; van Straten *et al*., 2005; Takahashi *et al*., 2006, 2007; Le *et al*., 2007; Balalaie *et al*., 2008; Trivedi *et al*., 2008; Fotie *et al*., 2010). Thus, 1,2-dihydroquinoline-6-oles and their ester derivatives were biologically (**a**ntitrypanosomally) active at micromolar concentrations (Fotie *et al*., 2010). It was also determined, that 6-oxy-2,2,4-trimethyl-1,2-dihydroquinoline and 6-oxy-2,2,4-trimethyl-1,2-tetrahydroquinoline at concentrations of 100, 50, 25, 12.5, and 6.25 ug ml^{-1} demonstrate bactericidal and bacteriostatic activity against laboratory M. tuberculosis H37 Rv indicator (the sample was provided by the museum of the local TB dispensary) and are thus highly effective antituberculous compounds (Litvinov *et al*., 2009). In terms of percentages, the following concentrations are effective: 0.01, 0.005, 0.0025, 0.00125, and 0.000625%. It is, therefore, interesting to study the effect of 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline, 6-hydroxy-2,2,4-trimethyl-1,2,3,4-tetrahydroquinoline, and their derivatives on woody plants with concentrations between 0.01–0.1%. Due to its importance as substructures in a wide range of natural and designed products, still, great efforts continue to be directed to the development of new quinoline-based structures (Li *et al*., 1985; Mohammed *et al*., 1992; Jain *et al*., 1994; Croisy-Delcey *et al*., 2000; Abadi, Brun, 2003; Shujiang *et al*., 2005; Elkholy, Morsy, 2006; Marjani *et al*., 2011; Mosalam *et al*., 2011a,b; Azizian *et al*., 2014; Ghoneim, Assy, 2015; Manahelohe *et al*., 2015a,b).

In all the existing studies, the effect of quinolinic compounds on the growth of the sprouts of woody plants was assessed on the 20th day of the experiment (Moiseeva *et al*., 2012a, Kalaev *et al*., 2013). However, the effect of synthesized chemical quinolinic compounds in the later stages of woody plant development (7 months after the start of the experiment) has not been studied yet. It is therefore of great importance to conduct a longitudinal study and measure the height of ornamental woody plants over longer time intervals (e.g., 7 months after the application of the growth regulator) in order to determine whether the growth stimulating effect lasts or deteriorates over time. It should be noted that the effect of the same factor may be species-specific for different plants, which makes it significantly more difficult to determine the optimal concentrations of the compounds. Seed progeny, sprouts, and even adult plants may react differently to the stimulators, which are, in fact, stress factors of various intensity.

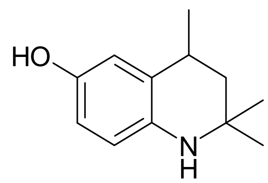
Highly decorative species of *Rhododendron* genus have also become more popular lately (Baranova *et al*., 2018; Burmenko *et al*., 2018a,b). They are planted in urban and residential areas, and their propagation requires additional stimulators of growth and seed germination.

Therefore, the aim of our research was to study the effect of synthesized organic compounds of 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline, its derivatives, and hydrogenated analogs on the height of seedlings, when used for pre-sowing seed treatment of the following ornamental woody plants – *Rhododendron ledebourii* and *Rhododendron smirnowii*.

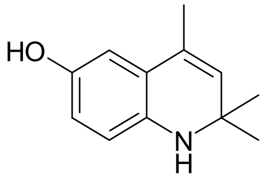
2. MATERIALS AND METHODS

In this study, it was used the following ornamental plants: woody plants *Rhododendron ledebourii* Pojark. And *Rhododendron smirnowii* Trautv. *Rhododendron ledebourii* is a perennial plant endemic for Altai and Mongolia. *Rhododendron smirnowii* is native to the forests and mountains of Caucasus, Adjara, and Turkey. *Rhododendron ledebourii* is a semi-evergreen shrub, and *Rhododendron smirnowii*, an evergreen shrub. In a controlled environment, both species grow up to 2-meter height and are highly decorative (Alexandrova, 2003). The long history of studying these species at the B.M. Kozo-Polyansky Botanical Garden of Voronezh State University has demonstrated that *Rhododendron ledebourii* is a winter-hardy, drought-resistant, and fruit-bearing shrub (Moiseeva *et al*., 2012b; Baranova 2013b). *Rhododendron smirnowii* is also quite winter-hardy, though less drought-resistant. It also grows slower than *Rhododendron ledebourii* (Alexandrova, 2003; Vostrikova, 2011).

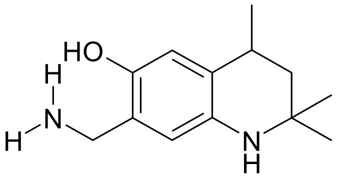
The research was conducted at the B.M. Kozo-Polyansky Botanical Garden of Voronezh State University in 2017. The study focused on the following organic compounds synthesized at the Department of Organic Chemistry of Voronezh State University*:*



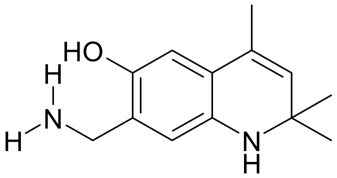
6-hydroxy-2,2,4-trimethyl-1,2,3,4-tetrahy_ droquinoline (stimulator 1),



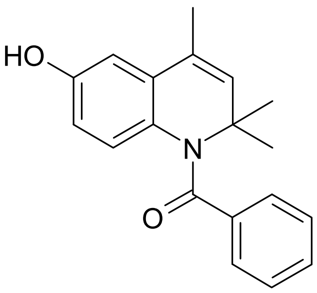
6-hydroxy-2,2,4-trimethyl-1,2-dihydroquino_ line (stimulator 2),



7-[(dimethylamino)methyl]-6-hydroxy-2,2,4-tri_ methyl-1,2,3,4-tetrahydroquinoline (stimulator 3),



7-[(dimethylamino)methyl]-6-hydroxy-2,2,4-trime_ thyl-1,2-dihydroquinoline (stimulator 4), and



1-benzoyl-6-hydroxy-2,2,4-trimethyl-1,2-dihydro_ quinoline (stimulator 5), and the way they influence the height of the seedlings of *Rh. ledebourii* and *Rh. smirnowii.*

The stimulator 1 (6-hydroxy-2,2,4-trimethyl-1,2,3,4-tetrahydroquinoline) and stimulator 2 (6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline) were synthesized from commercially available 6-ethoxy-2,2,4-trimethyl-1,2-dihydroquinoline (etho_ xychine) by the known method (Ivanov *et al.*, 1979). By aminomethylation of stimulators 1 and 2 with bis(dimethylamino)methane resulted in stimulator 3 (7-[(dimethylamino)methyl]-6-hydro_ xy-2,2,4-trimethyl-1,2,3,4-tetrahydroquinoline) and stimulator 4 (7-[(dimethylamino)methyl]-6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline), respectively. The stimulator 5 (1-benzoyl-6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline) was obtained as a result of successive reactions of acylation of stimulator 2 an excess of benzoyl chloride and subsequent alkaline hydrolysis of the resulting diacyl-derivative.

Prior to the sprouting process, the seeds of *Rh. ledebourii*, *Rh. smirnowii* were soaked in water solutions of the above-listed compounds with concentrations of 0.01%, 0.05%, and 0.1% for 18 hours. The control group consisted of the same type of seeds soaked in a tap water solution of a commonly used growth stimulator, Epibrassinolide (commercial fraction *Epin Extra* produced by *NNPP NEST M*, Russia), with the concentration of 0.05% (in accordance with the instruction). In the case of each of the studied concentrations of the acids, as well as the control group, the experiment was conducted three times using a set of 100 seeds. After soaking, the rhododendron seeds were placed in Petri dishes containing blotting paper and germinated in the laboratory conditions at a constant temperature of 22 °C. On the 21st day, the sprouts were planted in containers filled with high-moor peat and then kept in a greenhouse. The height of the seedlings of *Rhododendron* was measured with a ruler, 7 months after the start of the experiment. Sprouts are formed during the early stage of plant ontogenesis, which starts after the germination stage, i.e., when the seed coat develops, and finishes when the first leaf of the hypocotyledonous stem (the shoot rising from the plumule) develops (Korovkin, 2007). After the first true leaves appear, young plants are considered seedlings (Korovkin, 2007). The results were statistically processed using the STADIA software package. The procedures of data grouping and processing were described by A. P. Kulaichev (2006). The mean values were compared using Student's t-test. The variances were compared using the F-test.

3. RESULTS AND DISCUSSION:

The results of the treatment of seeds with the chemical compounds on the height of *Rh. ledebourii* seedlings 7 months after the start of the experiment are given in Table 1 and in Figure 1. It demonstrates that 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline (stimulator 2) appears to have strong stimulating effect with any of the studied concentrations: 0.01, 0.05, and 0.1% (differences with the control group are reliable, $p<0.001$). Dihydroquinolines (stimulators 4 and 5) and their substitutes 7-[(dimethylamino)methyl]- and especially 1-benzoyl- proved to have the stimulating effect at any of the studied concentrations (Table 3). 6-hydroxy-2,2,4-trimethyl-1,2,3,4-tetrahydroquinoline (stimulator 1) and 7-[(dimethylamino)methyl]-6-hydroxy-2,2,4-trimethyl-1,2,3,4-tetrahydroquinoline (stimulator 3) appeared to be less active. 7 months after the start of the experiment, the height of *Rh. ledebourii* seedlings increased by 17.9–89.3% (Table 3).

For *Rh. smirnowii*, 7 months after the seed treatment with the studied chemical compounds, the concentration of 0.1% proved to be the most effective (Table 2, Fig. 2) and increased the plants' height of 57.1–14.3% (Table 4).

The effect of certain quinolines on seed germination and the size of seedlings of *Rh. Ledebouriion*on, the 20th day of the experiment was investigated earlier. It was demonstrated that 2,2,4-trimethyl-1,2,3,4-tetrahydroquinoline and 2,2,4-trimethyl-1,2-dihydroquinoline (with a concentration of 0.1%) have a stimulating effect on both the seed germination and the height of the sprouts of *Rhododendron ledebourii* (Moiseeva *et al*., 2012a; Kalaev *et al*., 2013).

Besides *Rh. ledebourii*, 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline also had the strongest stimulating effect on *Rh. smirnowii* (Table 2). 7 months after the start of the experiment, the height of *Rh. smirnowii* seedlings increased by 21.4-57.1% (Table 4). 6-Hydroxy-2,2,4-trimethyl-1,2,3,4-tetrahydroquinoline was less effective, with the increase in the height of the seedlings (as compared to the control group) being 14.3-28.6% (Table 2, 4). 1-Benzoyl-6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline at concentrations of 0.05 and 0.1% (Tables 2, 4) also demonstrated a stimulating effect.

Thus, dihydroquinolines appear to have the strongest stimulating effect, with benzoyl boosting the effect of the stimulator, while tetrahydroquinolines are less active. Previous studies have determined that the detected **a**ntitrypanosomal activity of 1,2-dihydroquinoline-6-oles and their ester derivatives at micromolar concentrations are higher in the compounds containing benzene substitutes for the nitrogen atom (Fotie *et al*., 2010). However, the latter have different cytotoxicity. 1-benzyl-6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline acetate (**I**) (1-benzyl--6-hydroxy-1,2-dihydro-2,2,4-trimethylquinolin-6-yl acetate) was the most effective and had low cytotoxicity. Its activity involves the formation of the precursor 1-benzyl-6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline (1-benzyl--6-hydroxy-1,2-dihydro-2,2,4-trimethylquinolin) (**II**) (Fotie *et al*., 2010), which is the structural analogue of 1-benzoyl-6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline (1-benzyl--6-hydroxy-1,2-dihydro-2,2,4-trimethylquinolin) (stimulator **5**) we used in our study (Fig. 3) (Fotie *et al*., 2010).

For the plants of *Rhododendron* L. genus, the strongest stimulating effect was demonstrated by all the studied compounds with a concentration of 0.1%.

For *Rh. ledebourii* and *Rh. smirnowii* the most effective are the same synthesized chemical compounds: 6-hydroxy-2,2,4-trimethyl-1,2,3,4-tetrahydroquinoline, 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline, and 1-benzoyl-6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline with concentrations of 0.01, 0.05, and 0.1%.

4. CONCLUSIONS:

For the studied species of *Rhododendron* genus, the compounds of 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline, its derivatives, and hydrogenated analogs with the concentration of 0.1% proved to be the most efficient. Dihydroquinolines with concentrations of 0.05 and 0.1% appear to have the strongest stimulating effect on perennial woody plants, with benzoyl boosting the effect of the stimulator, while tetrahydroquinolines are less active. The effect of synthesized chemical compounds of 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline and its hydrogenated analog on woody plants of the same genus is not species specific. These compounds, when applied with the pre-sowing seed treatment of *Rh. ledebourii*, *Rh. smirnowii* result in an increase in the height of the seedlings by 3.6-89.3%, 14.3-57.1%, respectively. Thus it is suggested using the compounds of 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline, its derivatives, and hydrogenated analogs as growth stimulators for ornamental woody plants. The compounds of the quinoline series were tested for genotoxicity by the cytological method in the model object (*Betula pendula*) and recognized as environmentally friendly (Butorina *et al*., 2002). The cytogenetic responses for *Betula pendula* and *Rhododendron* are identical, so positive compounds influence for *Betula pendula* cells because of increasing of metabolic activity means the same for *Rhododendron* (Baranova *et al*., 2018; Burmenko *et al*., 2018a,b). Therefore, synthesized organic compounds can be recommended as effective growth stimulators.

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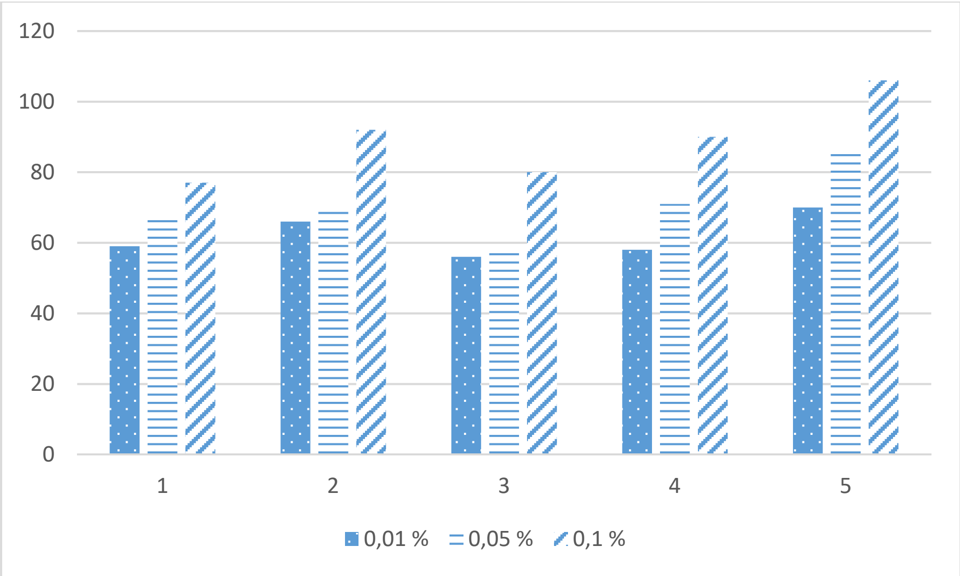

Figure 1. *Comparative height (in mm) of Rh. ledebourii seedlings 7 months after the start of the experiment for the compounds 1-5.*

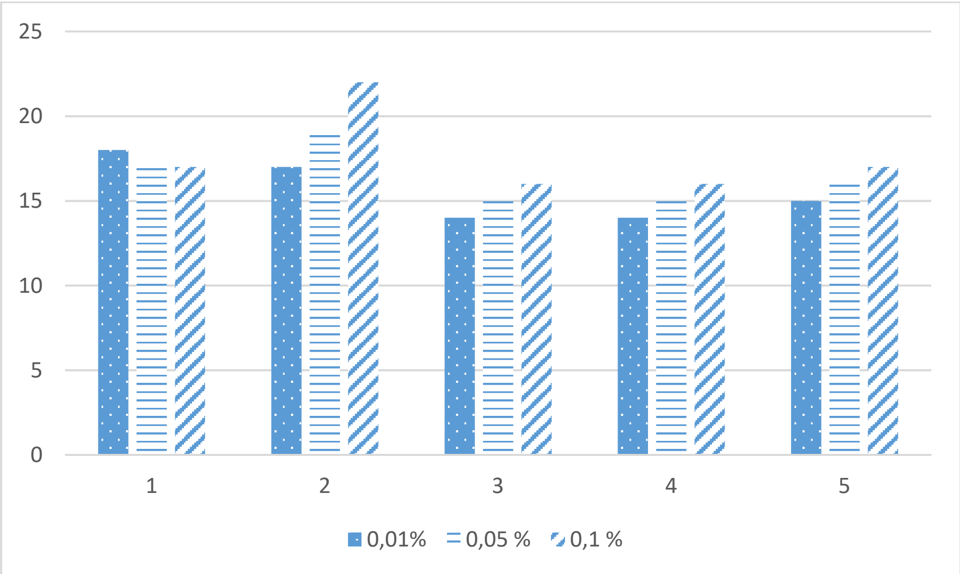

Figure 2. *Comparative height (in mm) of Rh. smirnowii seedlings 7 months after the start of the experiment for the compounds 1-5*

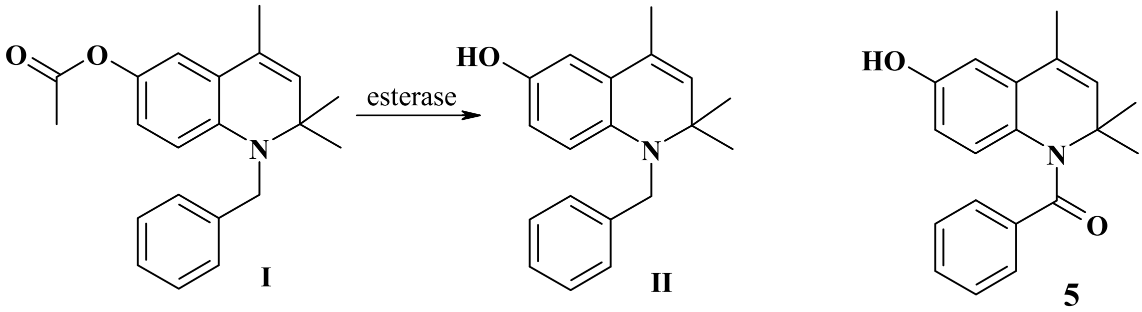

Figure 3. *Chemical formulae of the compounds used in the experiment*
I : 1-benzyl-6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline acetate
II : 1-benzyl-6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline
5 : 1-benzoyl-6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline

Table 1. *The height (in cm) of Rh. ledebourii seedlings 7 months after the start of the experiment*

Concen tration	Control group, %	Epin Extra group, %	Stimulator 1	Stimulator 2	Stimulator 3	Stimulator 4	Stimulator 5
0.01%			5.9±0.2**1	6.6±0.1***3	5.6±0.2	5.8±0.2*	7.0±0.2***3
0.05%	5.6±0,2	5.7±0,2	6.8±0.2***3	7.0±0.2***3	5.8±0.2*	7.1±0.2 ***3	8.6±0.3***3
0.1%			7.7±0.2***3	9.2±0.2***3	8.0±0.2***3	9.0±0.2***3	10.6±0.3***3

Note for Table 1-2:

** – differences with the control group are reliable (p<0.05)*

** – differences with the control group are reliable (p<0.01)*

** – differences with the control group are reliable (p<0.001)*

[1] - differences with the Epin Extra group are reliable (p<0.05);

[2] - differences with the Epin Extra group are reliable (p<0.01);

[3] - differences with the Epin Extra group are reliable (p<0.01);

6-hydroxy-2,2,4-trimethyl-1,2,3,4-tetrahydroquinoline (stimulator 1),
6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline (stimulator 2),
7-[(dimethylamino)methyl]-6-hydroxy-2,2,4-trimethyl-1,2,3,4-tetrahydroquinoline (stimulator 3),
7-[(dimethylamino)methyl]-6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline (stimulator 4),
1-benzoyl-6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline (stimulator 5).

Table 2. *The height (in cm) of Rh. smirnowii seedlings 7 months after the start of the experiment*

Concen tration	Control group, %	Epin Extra group, %	Stimulator 1	Stimulator 2	Stimulator 3	Stimulator 4	Stimulator 5
0.01%			1.8±0.1*[1]	1.7±0.1*[1]	1.4±0.1	1.4±0.1	1.5±0.1
0.05%	1.4±0,2	1.4±0,2	1.7±0.1*[1]	1.9±0.2**[2]	1.5±0.1	1,.5±0.1	1.6±0.1*
0.1%			1.7±0.1[1]	2.2±0.2**[2]	1.6±0.1*	1.6±0.1*	1.7±0.1*

Table 3. *The height (in cm) of Rh. ledebourii seedlings 7 months after the start of the experiment*

Concent ration	Epin, %	Stimulator 1	Stimulator 2	Stimulator 3	Stimulator 4	Stimulator 5
0.01%		28.6	21.4	–	–	–
0.05%	–	21.4	35.7	–	–	14.3
0.1%		21.4	57.1	14.3	14.3	21.4

Table 4. *The increase (in %) in the height of Rh. smirnowii seedlings 7 months after the start of the experiment*

Concen tration	Epin, %	Stimulator 1	Stimulator 2	Stimulator 3	Stimulator 4	Stimulator 5
0.01%		28.6	21.4	–	–	–
0.05%	–	21.4	35.7	–	–	14.3
0.1%		21.4	57.1	14.3	14.3	21.4