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QUINOLINE DERIVATIVES AS GROWTH REGULATORS FOR ORNAMENTAL PLANTS

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ABSTRACT

It is investigated the effect of synthesized organic compounds of 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline, its derivatives, and hydrogenated analogs. These compounds affected the height of seedlings when they were used for pre-sowing seed treatment of the following ornamental plants: annual ornamental grass – scarlet sage (*Salvia splendens*) and woody plant – yellow rhododendron (*Rhododendron luteum*). Prior to the sprouting process, the seeds of *Rh. luteum* and *S. splendens* were soaked in water solutions of compounds with concentrations of 0.01%, 0.05%, and 0.1% for 18 hours. Dihydro- and tetrahydroquinolines with a concentration of 0.05% proved to be the most effective for both plants. For *Rhododendron luteum*, the compounds of 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline, its derivatives, and hydrogenated analogs with a concentration of 0.1% proved to be the most effective. Dihydroquinolines at concentrations of 0.05 and 0.1% proved to have the strongest effect when applied to the studied perennial woody plant (*Rhododendron luteum*). Dihydroquinoline at the concentration of 0.05% also proved to be effective when applied to the annual grass (*Salvia splendens*). For annual *S. splendens*, tetrahydroquinoline at concentrations of 0.01 and 0.05% appeared to be the most effective. The pre-sowing seed treatment of grass *Salvia splendens* and woody plant *Rhododendron luteum* with the studied compounds demonstrated that their effect on the height of the seedlings is species-specific. The pre-sowing seed treatment of *Rh. luteum* and *S. splendens* allows increasing the height of the seedlings by 3-61 % and 17-25 %, respectively. It is suggested using the compounds of 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline, its derivatives, and hydrogenated analogs as effective growth stimulators for ornamental grasses and woody plants.

Keywords: quinolinic compounds, growth regulators, grasses, woody plants.

1. INTRODUCTION

Several heterocycles have shown biological activity: a potent antibacterial (Brown *et al.*, 2004), anti-inflammatory (Gavrilov *et al.*, 1988), antitrypanosomal (Fotie *et al*., 2010) and other effects. The same quinolinic compounds at different concentrations may either stimulate or inhibit the biological processes (Gavrilov *et al.*, 1988; Litvinov, 1998; Dorey *et al*., 2000; Brown *et al*., 2004; Le *et al*., 2007; Fotie *et al*., 2010).

Some papers also study the biological effect of quinolinic compounds, such as dihydro– and tetrahydroquinoline, on seed germination and the root growth of the stem cuttings of woody plants (Shmyreva, 2000; Butorina *et al*., 2002; Baranova, 2013 a). Over the last years, attempts have been made to synthesize new quinolinic compounds that can be used as growth regulators (Dorey *et al*., 2000; Croisy-Delcey *et al*., 2000; Pravin *et al*., 2000ab, 2003; Abadi, Brun, 2003; Denmark, Venkatraman, 2006). The effect of certain quinolines on seed germination and the size of the seedlings of *Rhododendron ledebourii* was also investigated (Moiseeva *et al*., 2012 a; Kalaev *et al*., 2013). However, the effect of 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline, its derivatives, and hydrogenated analogs on the growth of other plants has not been studied yet.

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 plants: annual ornamental grass – scarlet sage (*Salvia splendens*) and woody plant – yellow rhododendron (*Rhododendron luteum*).

The annual ornamental grass, scarlet sage (*Salvia splendens* Ker Gawl.), was selected as the study material because it is often planted in urban gardens and grows slowly in the early stages of its development (Nikolaenko 1971, Gladky 1977). Highly decorative deciduous shrub yellow rhododendron (*Rhododendron luteum* Sweet.) is quite winter-hardy and drought-resistant (Alexandrova 2003; Vostrikova 2011; Moiseeva *et al*., 2012 b; Baranova, 2013 b). It is planted in urban and residential areas, and its propagation requires additional stimulators of growth and seed germination.

2. MATERIALS AND METHODS

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 (compound 1),

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

7-[(dimethylamino)methyl]-6-hydroxy-2,2,4-trime_ thyl-1,2,3,4-tetrahydroquinoline (compound 3),

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

1-ben_zoyl-6-hydroxy-2,2,4-trimethyl-1,2-dihy_ droquinoline (compound 5), and the way they influence the height of seedlings of *Rh. luteum.*

The effect of 6-hydroxy-2,2,4-trimethyl-1,2,3,4-tetrahydroquinoline and 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline on the height of the “Hot fire” variety of scarlet sage (*Salvia splendens* Ker Gawl.) was also studied.

Prior to the sprouting process, the seeds of *Rh. luteum* and *Salvia splendens* 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% (following the instruction of commercial fraction). 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 luteum* was measured with a ruler, 7 months after the start of the experiment. After the first true leaves appear, young plants are considered seedlings (Korovkin 2007).

The seeds of *S. splendens* were sown in containers filled with a mixture of soil and sand (3 parts soil/1 part sand) and kept in a greenhouse at 20 °C, as recommended in (Nikolaenko 1971, Gladky 1977). Seed germination was evaluated on the 20th day of the experiment. On the 42nd day of the experiment, the seedlings, having been preliminarily hardened for 12 days, were removed from the greenhouse and planted on the field. The field experiment was designed according to B. A. Dospekhov (1985). The height of the seedlings was measured on the 42nd day using a ruler. 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. The coefficient of variation (Cv) was counted, according to G. F. Lakin (1990). If Cv was below 10%, it meant that the degree of variation was low, with Cv between 10 and 25%. The degree of variation was medium, and when Cv was over 25%, the degree of variation was high (Lakin 1990). To estimate the influence of various concentrations of the chemical compounds on the height of the plants, a one-way analysis of variance was used. The power of influence was estimated, according to Snedecor (in %).

3. RESULTS AND DISCUSSION:

The height of the seedlings of *Rhododendron luteum* 7 months after the seeds were treated with the studied organic compounds are given in Table 1 and Figure 1. The seedlings in all the experimental groups were higher than the ones in the control group, with 6-hydroxy-

2,2,4-trimethyl-1,2-dihydroquinoline (compound 2) demonstrating the stronger stimulating effect than 6-hydroxy-2,2,4-trimethyl-1,2,3,4-tetrahy_ droquinoline (compound 1).

It is demonstrated that 6-hydroxy-2,2,4-trimethyl-1,2,3,4-tetrahydroquinoline (compound 1), 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline (compound 2) and 1-benzoyl-6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline (compound 5) appear 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). 1-Benzoyl-6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline shows the strongest stimulating effect and 7-[(dime_ thylamino)methyl]-6-hydroxy-2,2,4-trime_ thyl-1,2,3,4-tetrahydroquinoline (compound 3) appears to be less active. But 7-[(dime_ thylamino)methyl]-6-hydroxy-2,2,4-trimethyl-1,2,3,4-tetrahydroquinoline (compound 3) and 7-[(dimethylamino)methyl]-6-hydroxy-2,2,4-trime_ thyl-1,2-dihydroquinoline (compound 4) at concentrations of 0.05 and 0.1% (Tables 1, 2) also demonstrated a stimulating effect. However, 7-[(dimethylamino)methyl]-6-hydroxy-2,2,4-trime_ thyl-1,2-dihydroquinoline (compound 4) is more effective. 7 months after the start of the experiment, the height of *Rh. luteum* seedlings increased by 3.0–61.2% (Table 2). For *Rh. luteum* the strongest stimulating effect was demonstrated by all the studied compounds with the concentration of 0.1%.

The study also determined the effect of the chemical compounds on the height of *Salvia splendens* and the variation coefficient for this parameter (Table 3). Variance analysis demonstrated that the studied quinolinic compounds influence the height of plants. The power of influence is given in Table 4.

Quinolinic compounds 6-hydroxy-2,2,4-trimethyl-1,2,3,4-tetrahydroquinoline with concentrations of 0.01% and 0.05% and 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline with the concentration of 0.05% can be used as growth stimulators for scarlet sage plants, increasing their height by 17-25%.

4. CONCLUSIONS:

The conducted experiments demonstrated that the stimulators have both similar and species-specific effects on annual grasses and perennial woody plants. 6-Hydroxy-2,2,4-trimethyl-1,2,3,4-tetrahydroquinoline and 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline with the concentration of 0.05% have the most substantial growth stimulating effect on the seedlings of all the studied plant species. However, the effect of the compounds on annual grass is different from the one they have on woody plants. For the annual grass tetrahydroquinoline with concentrations of 0.01% and 0.05% proved to be the most effective. For *Rhododendron luteum* compounds of 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline, its derivati_ ves, and hydrogenated analogs with the concentration of 0.1% proved to be the most effective. Dihydroquinoline at the concentration of 0.05% also proved to be effective when applied to the annual grass (*Salvia splendens*), while the other studied concentrations did not influence the height of the seedlings. The effect of synthesized chemical compounds of 6-hydroxy-2,2,4-trime_ thyl-1,2-dihydroquinoline and its hydrogenated analog on grasses and woody plants is species-specific. Tetrahydroquinolines are more effective than dihydroquinolines for the annual grass (*Salvia splendens*). Dihydroquinolines are stronger than tetrahydroquinolines for the woody plant (*Rhododendron luteum*). The pre-sowing seed treatment of *Rh. luteum* and *S. splendens* allows increasing the height of the seedlings by 3-61 % and 17-25 %, respectively. It is suggested using the compounds of 6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline, its derivatives, and hydrogenated analogs as effective growth stimulators for grasses and woody plants.

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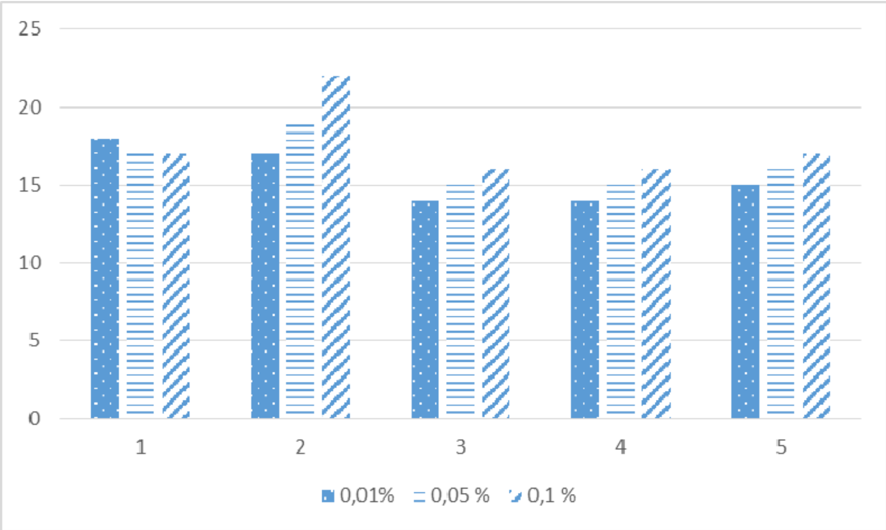

Figure 1. *Comparative height (in mm) of Rh. luteum seedlings 7 months after the start of the experiment for the compounds 1-5*

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

Concentration	Control group, %	Epin Extra group, %	compound 1	compound 2	compound 3	compound 4	compound 5
0.01 %			6.9±0,2*	7.6±0,1^{**2}	6.8±0,2	6.8±0.2	7.7±0.2^{**2}
0.05 %	6.7±0,2	6.9±0,2*	7.8±0,2^{**2}	7.9±0,2^{**2}	7.0±0,2*	7.1±0.2 ^{*1}	8.9±0.3^{***3}
0.1 %			8.4±0,2^{***3}	9.4±0,2^{***3}	8.3±0.2^{***3}	9.5±0.2^{***3}	10.8±0.3^{***3}

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

Table 2. *The increase (in %) in the height of Rh. luteum seedlings 7 months after the start of the experiment*

Concentration	Epin, %	compound 1	compound 2	compound 3	compound 4	compound 5
0,01%		3.0	13.4	–	–	14.9
0,05%	–	16.4	17.9	4.5	6.0	32.8
0,1%		25.3	40.3	23.9	41.8	61.2

***Table 3.** The height of Salvia splendens seedlings after the pre-sowing seed treatment with quinolinic compounds*

concentration, %	Average height of the plants, cm	Max - min, cm	Variation / Cv, %	Increase in the height of the plants, %
Control group	15.8±0.6	14 – 20	4.0 / 12.7	–
Epin Extra group	13.9±0.7*	12 – 18	4.3 / 15.1	–
6-hydroxy-2,2,4-trimethyl-1,2,3,4-tetrahydroquinoline (stimulator 1)				
0,01%	18.5±0.3**[2]	17 – 20	1.2[a] / 5.9	17,1
0,05%	19.8±0.5***[2]	18 – 22	2.2 / 7.6	25,3
0,1%	15.3±0.4	14 – 17	1.3 / 7.8	–
6-hydroxy-2,2,4-trimethyl-1,2-dihydroquinoline (stimulator 2)				
0,01%	15.8±0.3[1]	14 – 17	1.1[a] / 6.3	–
0,05%	18.8±0.2***[2]	18 – 20	6.2[б] / 4.3	19,0
0,1%	14.7±0.2	14 – 16	4.6[б] / 4.8	–

Reference: Cv - variation coefficient; * - 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 ($p<0.001$); [a] – differences with the Epin Extra group are reliable ($p<0.05$); [б] – differences in variation within the experimental group and control group are reliable ($p<0.01$).

***Table 4.** The power of influence (in %) of the stimulator on the height of Salvia splendens on the 42nd day of the experiment*

compound	as compared to the control group	as compared to the Epin Extra group	as is
compound 1	5.2**	7.7***	7.3***
compound 2	4.8***	7.0***	9.1***

Reference: ** - the influence of the factor is reliable ($p<0.01$); *** - the influence of the factor is reliable ($p<0.001$).