PERIÓDICO TCHÊ QUÍMICA
ARTIGO ORIGINAL

USO DE NOVOS COMPOSTOS DA SÉRIE QUINOLINA COMO ESTIMULANTES DE CRESCIMENTO E RENDIMENTO DE CULTURAS AGRÍCOLAS

USE OF NEW COMPOUNDS OF THE QUINOLINE SERIES AS GROWTH AND YIELD STIMULANTS OF AGRICULTURAL CROP

ИСПОЛЬЗОВАНИЕ НОВЫХ СОЕДИНЕНИЙ ХИНОЛИНОВОГО РЯДА КАК СТИМУЛЯТОРОВ РОСТА И УРОЖАЙНОСТИ СЕЛЬСКОХОЗЯЙСТВЕННЫХ КУЛЬТУР

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RESUMO

Introdução: Diversos métodos foram desenvolvidos para sintetizar compostos orgânicos que possuem atividades biológicas específicas. **Objetivo:** O objetivo desta pesquisa foi estudar o efeito de compostos orgânicos sintetizados de fórmula geral: 1-alquil-2,2,4-trimetil-6-aminocarbotioil-1,2-dihidroquinolina e 1-alquil-2,2,4-trimetil-6-aminocarbotioil-1,2,3,4-tetra-hidroquinolina em indicadores de crescimento (como a germinação da semente, a altura, comprimento, largura e número de folhas da planta) e o rendimento da colheita agrícola. **Métodos**: Para identificar os efeitos biológicos dos compostos orgânicos sintetizados, foram selecionados parâmetros morfométricos de uma cultura anual de hortaliças (*Solanum melongena* L.). Foi analizasa a germinação de sementes, processos de crescimento e produtividade. Os processos de crescimento foram estudados por indicadores biométricos. Os indicadores biométricos incluíram a altura da planta, comprimento, largura e número de folhas. **Resultados e discussão:** Os estimuladores de crescimento mais eficazes de compostos da série 1-alquil-2,2,4-trimetil-6-aminocarbotioil-1,2-di-hidroquinolina e 1-alquil-2,2,4-trimetil-6-aminocarbotioil-1,2,3,4-tetraidroquinolina para berinjela comum foram revelados. As substâncias mais eficazes para *Solanum melongena* são 1,2,2,4-tetrametil-6- (1-piperidinilcarbotioil)-1,2,3,4-tetrahidroquinolina cloridrato e 4-[(1,2,2,4-tetrametil)Cloridrato de -1,2-dihidro-6-quinolinil)carbotioil]-1-piperazinilcarbaldeído nas concentrações testadas (0,01%; 0,05% e 0,1%), bem como os compostos da fórmula geral: 1- alquil-2,2,4-trimetil-6-aminocarbotioil-1,2,3,4-tetra-hidroquinolina em concentrações de 0,05% e 0,1%. Foi estabelecido que as substâncias químicas sintetizadas estimulam o crescimento da berinjela em comparação com a preparação comercial existente. Compostos da série 1-alquil-2,2,4-trimetil-6-aminocarbotioil-1,2-di-hidroquinolina e 1-alquil-2,2,4-trimetil-6-aminocarbotioil-1,2,3,4- a tetraidroquinolina aumenta a germinação das sementes de *Solanum melongena* de 30 a 80%, a massa vegetativa - de 10 a 40%, rendimento - de 28 a 46%. **Conclusões**: As tetraidroquinolinas são mais eficazes como estimulantes dos processos de crescimento (e produtividade) da berinjela comum. Os compostos contendo um substituinte di-hidro-6-quinolinil estimulam o crescimento e também aumentam o rendimento de *Solanum melongena*. A conveniência dos compostos da série quinolina para a produção de cultivo de vegetais é mostrada. Os estimuladores de crescimento usados aumentam o potencial adaptativo de *Solanum melongena*.

Palavras-chave*: reguladores de crescimento, processos de crescimento, compostos orgânicos sintetizados, germinação de sementes, rendimento*.

ABSTRACT

Background: Productivity is increased with breeding techniques and modes for obtaining highly productive cultivars, various agricultural activities, and the use of new technologies for growing planting material. Some of modes to increase productivity are simple. They use different growth stimulants. Many methods were developed to synthesize organic compounds that have stimulating biological activity and can be used as growth stimulants for agricultural crop. **Aim:** The purpose of this research was to study the effect of synthesized organic compounds of the general formula: 1-alkyl-2,2,4-trimethyl-6-aminocarbothioyl-1,2-dihydroquinoline and 1-alkyl-2,2,4-trimethyl-6-aminocarbothioyl-1,2,3,4-tetrahydroquinoline on growth indicators (by which we meant seed germination and plant height, length, width, and the number of leaves) and the yield of the agricultural crop. **Methods:** To identify the biological effects of the synthesized organic compounds, morphometric parameters of an annual vegetable crop (*Solanum melongena* L.) were selected. It is investigated seed germination, growth processes, and yield. Growth processes were studied by biometric indicators. Biometric indicators included the plant height, length, width, and the number of leaves. **Results and Discussion:** The most effective growth stimulators from compounds of the series 1-alkyl-2,2,4-trimethyl-6-aminocarbothioyl-1,2-dihydroquinoline and 1-alkyl-2,2,4-trimethyl-6-aminocarbothioyl-1,2,3,4-tetrahydroquinoline for common eggplant were revealed. The most effective substances for *Solanum melongena* are 1,2,2,4-tetramethyl-6-(1-piperidinylcarbothioyl)-1,2,3,4-tetrahydroquinoline hydrochloride and 4-[(1,2,2,4-tetramethyl-1,2-dihydro-6-quinolinyl)carbothioyl]-1-piperazinylcarbaldehyde hydrochloride in tested concentrations (0,01 %; 0,05 % and 0,1 %), as well as the compounds of the general formula: 1-alkyl-2,2,4-trimethyl-6-aminocarbothioyl-1,2,3,4-tetrahydroquinoline in concentrations of 0,05 % and 0,1 %. It was established that the synthesized chemical substances cause stimulation of the eggplant growth compared with existing commercial preparation. Compounds of the series 1-alkyl-2,2,4-trimethyl-6-aminocarbothioyl-1,2-dihydroquinoline and 1-alkyl-2,2,4-trimethyl-6-aminocarbothioil-1,2,3,4-tetrahydroquinoline increase the seed germination of *Solanum melongena* from 30 to 80 %, the vegetative mass - from 10 to 40 %, yield - from 28 to 46 %. **Conclusions:** Tetrahydroquinolines are most effective as stimulants of growth processes (and productivity) for common eggplant. Compounds containing a dihydro-6-quinolinyl substituent stimulate the growth and also increase the yield of *Solanum melongena.* The expediency of quinoline series compounds for the production of vegetable growing is shown. Used growth stimulators increase the adaptive potential of *Solanum melongena.*

Keywords: *growth regulators, growth processes, synthesized organic compounds, seed germination, yield*.

АННОТАЦИЯ

Предпосылки: Урожайность повышается за счет селекционных технологий и способов получения высокопродуктивных сортов, различных сельскохозяйственных работ и использования новых технологий выращивания посадочного материала. Некоторые из способов повышения продуктивности просты. Они используют разные стимуляторы роста. Разрабатываеся множество методов синтеза органических соединений, которые обладают стимулирующей биологической активностью и могут использоваться как стимуляторы роста сельскохозяйственных культур. **Цель:** Цель исследования состояла в изучении эффектов соединений общей формулы: 1-алкил-2,2,4-триметил-6-аминокарботиоил-1,2-дигидрохинолин и 1-алкил-2,2,4-триметил-6-аминокарботиоил-1,2,3,4-тетрагидрохинолин на ростовые показатели (под которыми мы понимали всхожесть семян и высоту растения, длину, ширину и количество листьев) и урожайность сельскохозяйственной культуры. **Методы:** Для выявления биологического действия синтезированных органических соединений были выбраны морфометрические параметры однолетней овощной культуры (*Solanum melongena* L.). Исследуется всхожесть семян, процессы роста и урожайность. Процессы роста изучали по биометрическим показателям. Биометрические показатели включали высоту растения, длину, ширину и количество листьев. **Результаты и Обсуждение:** Выявлены наиболее эффективные стимуляторы роста из соединений ряда 1-алкил-2,2,4-триметил-6-аминокарботиоил-1,2-дигидрохинолина и 1-алкил-2,2,4-триметил-6-аминокарботиоил-1,2,3,4-тетрагидрохинолина для баклажана обыкновенного. Наиболее эффективными веществами для *Solanum melongena* являются 1,2,2,4-тетраметил-6-(1-пиперидинилкарботиоил)-1,2,3,4-тетрагидрохинолин гидрохлорид и 4-[(1,2,2,4-тетраметил)-1,2-дигидро-6-хинолинил)карботиоил]-1-пиперазинилкарбальдегида гидрохлорид в тестируемых концентрациях (0,01 %; 0,05 % и 0,1 %), а также соединения общей формулы: 1- алкил-2,2,4-триметил-6-аминокарботиоил-1,2,3,4-тетрагидрохинолин в концентрациях 0,05 % и 0,1 %. Установлено, что синтезированные химические вещества вызывают стимуляцию роста баклажанов по сравнению с существующим коммерческим препаратом. Соединения ряда 1-алкил-2,2,4-триметил-6-аминокарботиоил-1,2-дигидрохинолин и 1-алкил-2,2,4-триметил-6-аминокарботиоил-1,2,3,4-тетрагидрохинолин увеличивают всхожесть семян *Solanum melongena* с 30 до 80 %, вегетативную массу - с 10 до 40 %, урожайность - с 28 до 46 %. **Выводы:** Тетрагидрохинолины наиболее эффективны в качестве стимуляторов ростовых процессов (и продуктивности) для баклажана обыкновенного. Соединения, содержащие дигидро-6-хинолинильный заместитель, стимулируют рост, а также увеличивают урожайность *Solanum melongena*. Показана целесообразность применения соединений хинолинового ряда для овощеводства. Используемые стимуляторы роста повышают адаптационный потенциал *Solanum melongena*.

Ключевые слова: *регуляторы роста, ростовые процессы, синтезированные органические соединения, всхожесть семян, урожайность*

1. INTRODUCTION

In recent years vegetable growing has been faced with many problems associated with an extreme increase in air temperature, lack of soil moisture, and the search for the most stable and unpretentious crops that can grow in such conditions. Breeding and testing are carried out and aimed at increasing the yield, resistance of agricultural plants to adverse environmental conditions (Dyakov *et al.*, 2009). Productivity is increased with breeding techniques and modes for obtaining highly productive cultivars, various agricultural activities, and the use of new technologies for growing planting material. It is known that different genetic systems control the productivity potentials of cultivated plants and their environmental sustainability and relatively independent (Zhuchenko, 1994, 1995, 2009; Kilchevsky, Khotyleva, 1997). It was noted that the productivity of the fruiting plant and its resistance to adverse factors are antipodal in nature since the same metabolites are involved in their creation but in different quantities (Doroshenko, 2000). Thus, productivity and stability are formed from the same photosynthesis products but redistributed in different directions following genetic regulation (Doroshenko *et al.*, 2010). Studies show the presence of negative genetic correlation or even significant incompatibility between the high yield potential and tolerance to adverse conditions in many species of cultivated plants (Azzi, 1959; Rosielle, Hamblin, 1981; Kadyrov *et al.*, 1984), which indicates the need for a search other (non-breeding) methods for solving this problem, which may be the treatment of planting material with chemical stimulators.

Last years a lot of new compounds are recommended for use as plant growth and seed germination stimulants, fertilizers for vegetables, field (including sugar beet), and fruit crops used for food by humans. In this connection, ecologically safe substances play an important role. For example, when reproducing sugar beet hybrids, an increase in yield and sugar content of mother roots after the treatment of seeds with humic compounds has been revealed (Tsareva, 2013). Further, planting of these roots for the reproduction of hybrids improves the yield and sowing properties (germinating capacity) of seeds (Tsareva, 2013).

Maintenance of seed quality is mandatory for the sale of seed and assuring required plant population and final yields to end-user. Seed lots are evaluated based on their germination capabilities and vigor (Sudhakar *et al.*, 2016). However, many tests used to evaluate seed physiological characteristics require time and skilled labor, making it a costly process (Baranova, 2013; Sudhakar *et al.*, 2016). However, there are simple characteristics, for example, biometric indicators included plant height, length, width, and several leaves. They are suitable for the study of the agricultural crop.

One of the agricultural plants cultivated in recent years in Russia, in the Central Black Earth region, and even in the Non-Chernozem zone due to the more cold-resistant varieties obtained in breeding tests is an ordinary eggplant (Mamedov, 2002; Guber and Shentseva, 2011). Its fruits are tasty and healthy; they contain antioxidants in the seeds – steroid glycosides. These natural compounds delay the aging of living organisms and thereby contribute to their resistance to stress and disease (Mamedov, 2002). Due to the long vegetation period of eggplant common (*Solanum melongena* L.) in this zone, accelerated production of planting material is necessary, which is achieved using growth stimulators and seed germination, including synthesized chemical compounds.

Several researches have been carried out related to the development of methods for the synthesis of organic compounds that have certain types of biological activity and are promising drugs (Kashaev *et al.*, 2010 a, b, 2011). At the same time, one of the key problems of the functionally-oriented molecular design of new pharmacologically active compounds was and remained the problem of choosing an accessible substrate with great preparative capabilities (Kashaev *et al.*, 2010 a, b, 2011).

Heterocyclic series, including quinoline derivatives, being polyfunctional substrates, fully meet these requirements. A significant amount of data on the biological activity of compounds containing a quinoline fragment, including the activity and toxicity, has been published in the literature (Abadi, Brun, 2003; Saudi *et al.*, 2003; Abdel-Gawad *et al.*, 2005; Kashaev *et al.*, 2010 a, b, 2011). Some compounds have found application as chemotherapeutic drugs with antimicrobial, antiprotozoal, antifungal, and bronchodilatory activity (montelukast, quinifuril, chlorquinaldol, hydroxychlorin, chlorin) (Abadi, Brun, 2003; Saudi *et al.*, 2003; Abdel-Gawad *et al.*, 2005; Kashaev *et al.*, 2010 a, b, 2011; Ghoneim and Assy, 2015). Effective antimalarial drugs have been found among aminoquinolines. Iso-propylamide 2- (4-chloroanilino) cinchoninic acid exhibits anti-inflammatory and analgesic activity (Kashaev *et al.*, 2010 a, b, 2011).

Despite the fairly widespread use of derivatives quinolines, the potential for their research is far from being exhausted. A promising area of work, in connection with the growing need for the development of effective and safe preparation, is the synthesis of new heterocyclic systems containing other groups along with a quinoline fragment. It was shown that the most stable is the quinoline nucleus by the mass spectrometric method (Kashaev *et al.*, 2010 a, b, 2011).

Last years there are a lot of organic and inorganic compounds (Pentelkina and Pentelkina, 2002; Vasin *et al.*, 2008, 2009; Ostroshenko and Ostroshenko, 2011; Kadyrov and Schuchka, 2005; Baranova, 2013; Khodaei-Joghan *et al.*, 2018; Nesterkina *et al.*, 2019) and other original modes for growth-regulating (Shibaeva *et al.*, 2018). In the greenhouse production of several vegetables and ornamental plant species, a short diurnal temperature drop is used to reduce stem elongation as an alternative to chemical growth retardants (Shibaeva *et al.*, 2018). It was determined the effects of applying organic and chemical fertilizers under different irrigation regimes on sunflower (*Helianthus annuus* L.) morphological traits, yield components, grain yield, and grain quality (Khodaei-Joghan *et al.*, 2018). There are new effective synthesized quinoline compounds (Abadi and Brun, 2003; Saudi *et al.*, 2003; Abdel-Gawad *et al.*, 2005; Shujiang *et al.*, 2005; Denmark, Venkatraman, 2006; Kashaev *et al.*, 2010 a, b, 2011; Mosalam *et al.*, 2011 a, b; Azizian *et al.*, 2014; Shikhaliev *et al.*, 2014; Ghoneim and Assy, 2015).

A wide range of derivatives of 4-quinolinecarboxylic acid hydrazides has been obtained, containing 1,3,4-oxadiazole, 1,2,4-triazine, and 1,2,4-triazole rings, along with the quinoline fragment (Kashaev *et al.*, 2010 a, b, 2011). The synthesis of 2-R-6-R′-(5-X-2-oxo-1,2-dihydro-3H-indol-3-ylidene) quinoline-4-carbohydrazides was carried out by condensation of hydrazides of 4-quinolinecarboxylic acids with isatins (Kashaev *et al.*, 2010 b). Based on 2-methyl-4- (1,3,4-oxadiazol-2-yl) quinolines, the corresponding 2- [2- (2-nitrophenyl) -1-ethenyl] -6-R-4- (1,3 , 4-oxadiazol-2-yl) quinolines of the E-configuration. The cyclization of 2-[2-(2-am_ inophenyl)-1-ethenyl]-4-(1,3,4-oxadiazol-2-yl)qui_ noline, which is a reduction product of 2-[2- (2-nitrophenyl) -1- ethenyl] -4- (1,3,4-oxadiazol-2-yl) quinoline, 4-(1,3,4-oxadiazol-2-yl)-2,3-biquinoline was synthesized under the conditions of the Vilsmeier reaction (Kashaev *et al.*, 2010 a). Based on the results of biological tests of the synthesized substances, the expediency of searching for new physiologically active compounds in the series of 4-hetarylquinolines was confirmed (Kashaev *et al.*, 2011). Thus a lot of newly synthesized compounds containing the quinoline fragment show physiological activity.

The main objectives of this research were to study the effect of synthesized organic compounds of the general formula: 1-alkyl-2,2,4-trimethyl-6-aminocarbothioyl-1,2-dihydroquinoline and 1-alkyl-2,2,4-trimethyl-6-aminocarbothioyl-1,2,3,4-tetrahydroquinoline on growth indicators (by which we meant seed germination and plant height, length, width, and the number of leaves) and the yield of *Solanum melongena.*

2. MATERIALS AND METHODS

2.1. The synthesis of organic compounds

Acrylonitrile was copolymerized with 8-methacryloxy-quinoline in Dimethylformamide using azobisisobutyronitrile as the initiator. Both homopolymer and copolymers were characterized by different spectral and thermal methods (Mosalam *et al.*, 2011 b).

The monomer 8-methacryloxy-quinoline (MAQ) was prepared by the reaction of 8-hydroxyquinoline with either methacryloyl chloride or methacrylic acid in the presence of triethylamine and N,N′-dicyclohexylcarbodiimide, respectively (Mosalam *et al.*, 2011 a). Binary copolymerization of this new monomer with methyl acrylate (MA), acrylonitrile (AN) methyl methacrylate (MMA), styrene (ST), were performed in Dimethylformamide, using 1 mol% azobisisobutyronitrile as initiator at 65 °C (Mosalam *et al.*, 2011 a). The monomer reactivity ratios for the systems MAQ-MA, MAQ-AN, MAQ-MMA and MAQ-ST were found to be r1 = 0.695 ±

0.036, r2 = 0.62 ± 0.235; r1 = 0.273 ± 0.087, r2 = 0.259 ± 0.67; r1 = 0.356 ± 0.015, r2 = 1.615 ± 0.052 and r1 = 0.097 ± 0.003, r2 = 0.339 ± 0.027 respectively (Mosalam *et al.*, 2011 a).

Novel pyrimido[4,5-b]quinoline-tetraones (4 a-m) were prepared by the three-component reaction of 2-hydroxynaphthalene-1,4-dione (1), 6-amino-uracils (2), and aromatic aldehydes (3) in aqueous media and catalyzed by *p*-toluenesulfonic acid (Figure 1). This reaction provides a simple one-step procedure with the advantages of easy workup, good yield of products, and environmental friendliness (Azizian *et al.*, 2014). Sulfur as the element present in the synthesis of new hydroquinoline derivatives.

2–Amino–4-phenyl–5,6,7,8–tetrahydroqui_ noline–3–carbonitrile (3) was synthesized by treating cyclohexanone (1) with 2–benzylidenemalononitrile (2) in the presence of ammonium acetate (Elkholy and Morsy, 2006). The treatment of cyclohexanone (1) with the α,β-unsaturated nitrile derivative 2 in the presence of ammonium acetate afforded the tetrahydroquinoline derivative 3 (Elkholy and Morsy, 2006). A solution of cyclohexanone (1, 0.01 mol) in absolute ethanol (30 mL) containing an excess of ammonium acetate and the arylidene derivative 2 (0.01 mol) was heated under reflux from 3 to 5 h (Elkholy and Morsy, 2006). The separated solid material during the heating was collected by filtration and recrystallized from ethanol to yield the tetrahydroquinoline derivative 3 (Elkholy and Morsy, 2006). The reactivity of compound 3 towards dimethylformamide dimethyl acetal, carbon disulfide, urea, thiourea, formamide, formic acid, acetyl chloride, and isothiocyanate was studied (Elkholy and Morsy, 2006).

It was developed a three-component method for the synthesis of new thiocarboxamides containing in their composition the gidroquinoline cycle. The elemental sulfur was used in Wilgerodt-Kindler reaction for the thioamides synthesis. The thioamides series synthesis of hydroquinoline derivatives is based on Wilgerodt-Kindler reaction for 1-alkylhydroquinoline-6-carbaldehydes, amines, and sulfur. The structures of compounds were characterized by NMR-1H spectroscopy and elemental analysis. The data of NMR-1H (nuclear magnetic resonance) thioamides spectra are presented below.

Figure 2 is a general scheme for the synthesis of organic compounds of the series 1-alkyl-2,2,4-trimethyl-6-aminocarbothioyl-1,2-dihydroquinoline and 1-alkyl-2,2,4-trimethyl-6-aminocarbothioyl-1,2,3,4-tetrahydroquinoline.

A mixture of the corresponding hydroquinoline carboxaldehyde (1 mmol), amine (1.33 mmol), and elemental sulfur (1.33 mmol) in dimethylformamide (2 ml) was heated under reflux until the completion of the reaction (the control by the thin layer chromatography). After cooling, the reaction mass was poured into 5 ml of ice water with vigorous stirring. The solidified after grinding, and the precipitate was filtered, washed with water, and recrystallized from 75% ethanol. Non-hardening thiocarboxamides were treated with a double excess of hot 2M hydrochloric acid, filtered, and recrystallized from ethanol.

The structures of synthesized organic compounds are presented in Figures 3-7.

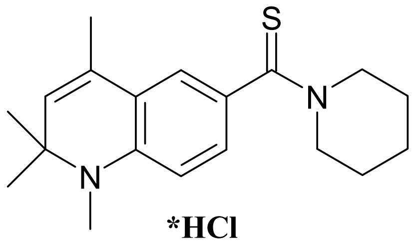

Figure 3. *1,2,2,4-tetramethyl-6-(1-piperidinylcarbothioyl)-1,2-dihydroquinoline hydrochloride (compound 1).*

The data of NMR-1H thioamides spectra: 1.29 (6H, s, (CH3) 2 -C2); 1.45-1.60 (6H, br.s, 3CH2 - piperidine); 1.89 (3H, s, CH3 -C4); 2.76 (3H, s, N-CH3); 3.60-4.30 (4H, br.s, 2CH2 - piperidine); 5.39 (1H, s, CH-DHC); 6.44 (1H, d, J = 8.54, arom); 6.95 (1H, d, J = 2.18, arom); 7.05 (1H, dd, J = 8.46, J = 2.18, arom.).

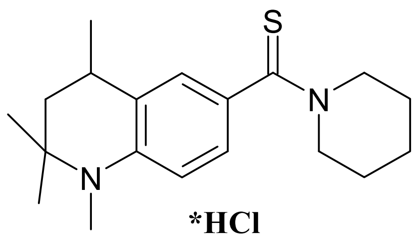

Figure 4. *1,2,2,4-tetramethyl-6-(1-piperidinylcarbothioyl)-1,2,3,4-tetrahydroquinoline hydrochloride (compound 2).*

The data of NMR-1H thioamides spectra: 1.17 (3H, s, (CH3) 2A-C2); 1.26 (3H, s, (CH3) 2B-C2); 1.27 (3H, d, J = 6.59, CH3 -C4); 1.40 (1H, t, J = 12.85, CH2A); 1.44-1.65 (6H, br.m., 3CH2 -piperidine); 1.83 (1H, dd, J = 13.04, J =

4.44, CH2B); 2.76 (1H, m, CH); 2.78 (3H, s, N-CH3); 3.50-4.30 (4H, br.m., 2CH2 -piperidine); 6.47 (1H, d, J = 9.18, arom); 7.03 (1H, dd, J = 6.79, J = 2.16, arom.); 7.04 (1H, s, arom.).

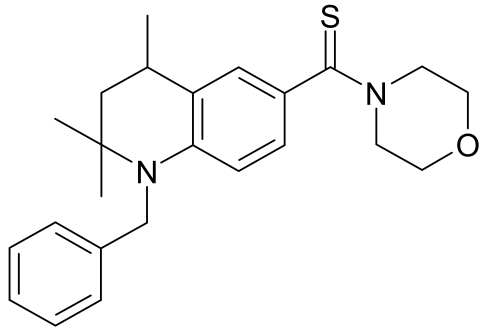

Figure 5. *1-benzyl-2,2,4-trimethyl-6-(4-morpholinylcarbothioyl)-1,2,3,4-tetrahydroquinoline (compound 3).*

The data of NMR-1H thioamides spectra: 1.24 (3H, s, (CH3) 2A-C2); 1.26 (3H, s, (CH3) 2B-C2); 1.32 (3H, d, J = 6.59, CH3 -C4); 1.64 (1H, t, J = 12.98, CH2A); 1.90 (1H, dd, J = 13.03, J = 4.72, CH2B); 2.96 (1H, m, CH); 3.50-4.20 (8H, m br, 4CH2 - morpholine); 4.26 (1H, d, J = 18, CH2A-benzyl); 4.78 (1H, d, J = 18.07, CH2B-benzyl); 6.13 (1H, d, J = 8.65, aroma.); 6.90 (1H, dd, J = 8.63, J = 2.13, arom); 7.15- 7.35 (6H, m, arom).

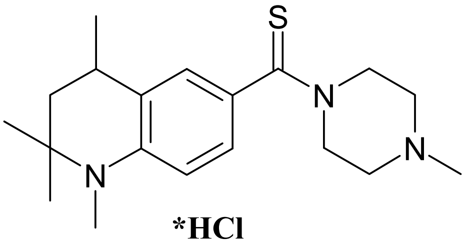

Figure 6. *1,2,2,4-tetramethyl-6-[(4-methyl-1-piperazinyl)carbothioyl]-1,2,3,4-tetrahydroquinoline hydrochloride (compound 4.)*

The data of NMR-1H thioamides spectra: 1.19 (3H, s, (CH3) 2A-C2); 1.28 (3H, s, (CH3) 2B-C2); 1.30 (3H, d, J = 7.31, CH3 -C4); 1.42 (1H, t, J = 12.45, CH2A); 1.85 (1H, dd, J = 13.08, J = 4.52, CH2B); 2.75 (3H, d, J = 4.55, N-CH3 -piperazine); 2.81 (3H, s, N-CH3 -TGQ); 3.08 (1H, m, CH); 4.10-4.70 (8H, br.m., 4CH2 -piperazine); 6.50-7.35 (3H, m, aroma.); 11.25 (1H, s, HCl).

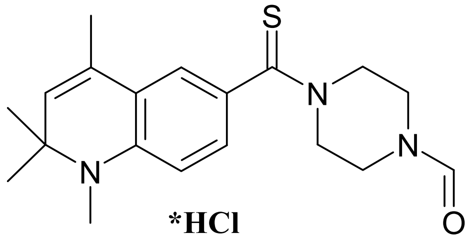

Figure 7. *4-[(1,2,2,4-tetramethyl-1,2-dihydro-6-quinolinyl)carbothioyl]-1-piperazinylcarbaldehyde hydrochloride (compound 5).*

2.2. The treatment of planting material

As an object of research, common eggplant (*Solanum melongena* L.) cv. Black Beauty was chosen. The material was purchased seeds of “Aelita” (Moscow) with a guaranteed shelf life, the quality of which corresponds to Russian Standards of high quality (varietal purity - 92-98 %, germination - not less 60%, humidity - no more 11 %). Seeds were soaked in water solutions of the synthesized compounds. The seeds of *Solanum melongena* were kept in water solutions of the above chemical compounds at concentrations of 0.01%, 0.05%, and 0.1% for 18 hours. As a traditional stimulator, the commercial preparation Epin-Extra (Russian produced by NNPP NEST M) in a working concentration according to the instructions for use - 0.05%. The control seeds were soaked in tap water. The experiment was carried out in triplicate (100 seeds in each). Seeds were germinated under laboratory conditions at a constant temperature of 22 °C.

The eggplant seedlings were counted to study laboratory germination and planted in boxes in a covered ground (greenhouse) on the 14th day after the germination. The laboratory germination of seeds was determined as the ratio of the number of germinated seeds to the total number of seeds and was expressed in %. Biometric indicators (the plant height, length, and width of leaves) were measured on the 50th day of the start of the experiment using a ruler. The plants were transferred from the greenhouse to the open ground on the 50th day of the beginning of the experiment, after preliminary hardening the seedlings (from 30 days). A field experiment was laid according to B. A. Dospehov (1985) by the method of split plots in triplicate. Eggplant seedlings were planted in open ground at the rate of 5 plants per 1 m^2 (50 thousand plants per 1 ha). Biometric indicators included the plant height, length, width, and the number of leaves. The number of leaves, which is considered the most objective sign of the degree of plant development (Korovkin, 2007, Zhidkih *et al*., 2012), was calculated on the 50th day of the start of the experiment. The number of leaves was counted from 50 plants of each variant and was found the average value. The yield was determined after fruit harvesting on 70th day after planting in open ground (120th day of the start of the experiment). The mass of fruits was measured using a balance from 4 m^2 and calculated for 1 m^2 (was devided at 4). The yield was expressed in kg/m^2.

Computer statistical processing was performed using the Stadia software package. Data on 50 plants of each variant were analyzed. The seed germination in control and experimental variants was compared according to the frequency agreement criterion using Z-statistics. The comparison of the mean values was carried out using Student's t-test according to A. P. Kulaichev (2006) work. The influence of the chemical treatment factor at different concentrations on growth rates was determined using a two-way analysis of variance.

3. RESULTS AND DISCUSSION:

The virtual screening of the obtained compounds is carried out with the help of PASS programe developed at the Institute of Bioorganic Chemistry of the Russian Academy of Medical Sciences (Moscow). Therefore opportunities for the practical use of substances were predicted. As it turned out, hydroquinoline thioamides with a high degree of probability (more than 70%) are biologically active compounds. Pharmacological side effects such as mutagenicity, carcinogenicity, teratogenicity ness, and embryotoxicity for synthesized substances are not predicted. It should also be marked that it is predicted the high growth-stimulating activity regarding plants for all thioamides.

The results of the influence of tested chemical compounds on the germination capacity of common eggplant (*Solanum melongena* L.) seeds of cv. Black Beauty is presented in Table 1. The greatest effect of increasing the germination capacity of ordinary eggplant was produced by compounds of the series 1-alkyl-2,2,4-trimethyl-6-aminocarbothioyl-1,2,3,4-tetrahydroquinoline, which are tetrahydroquinolines. There is a distinct tendency to increase seed germination with decreasing concentration in all considered compounds belonging to this series. Stimulators 1 (dihydroquinoline) and 5 (containing the dihydro-6-quinolinyl substituent) did not stimulate germination. The germination of eggplant seeds under the influence of synthesized organic substances in the tested concentrations increases from 32.4 to 89.3 %.

The height of the common eggplant plant grown from seeds treated with synthesized chemical compounds is shown in Table 2. It can be found from the table that stimulators 2 and 5 express the greatest stimulating effect in all tested concentrations. Stimulators 3 and 4 are effective in concentrations of 0.05 % and 0.1 %. All tested compounds exhibit a stimulating effect at a concentration of 0.1 %. Plant height under the influence of synthesized organic substances in the tested concentrations increases from 13.9 to 43.1%.

The leaf length of *Solanum melongena* after treating the seeds with synthesized chemical compounds is presented in Table 3. The table shows that their effect is similar to that on the plant height: stimulators 2 and 5 exhibits the greatest stimulating effect in all tested concentrations. Stimulators 3 and 4 are effective in concentrations of 0.05 % and 0.1 %. All tested compounds exhibit a stimulating effect at a concentration of 0.1%. The leaf length increases from 15.9 to 20.6 %.

All tested compounds at a concentration of 0.05 % and 0.1 % had a stimulating effect on the leaf width of common eggplant (Table 4), except for stimulator 1, which was effective only in a 0.1 % solution. The greatest effect was stimulators 2 and 5. The leaf width increases from 21.7 to 45.7 %.

The stimulating effect of chemical compounds on the number of leaves of *Solanum melongena* (Table 5) differed from that of the height of the plant and the leaf length. The most effective stimulator was 2. The number of leaves under the influence of synthesized organic substances in the tested concentrations increases from 3.9 to 28.9 %.

All the tested compounds at all concentrations, except for a 0.01 % solution of the stimulator 1, had a stimulating effect on eggplant yield (Table 6). The yield under the influence of synthesized organic substances in the tested concentrations increased from 28.1 to 46.9 %. The results of two-way analysis of variance confirm the influence of the factor of seed treatment with chemical compounds and concentration on biometric indicators: plant height ($P<0.01$), leaf length ($P<0.01$), leaf width ($P<0.01$), number of leaves ($P<0.05$) and yield

(P<0.05). Therefore, the obtained data shows that used growth stimulators increase the adaptive potential of *Solanum melongena.* Though productivity potentials of cultivated plants and their environmental sustainability are controlled by different genetic systems (Zhuchenko, 2009), it was noted that productivity and environmental sustainability is risen by several chemical substances (Titov *et al*., 2011; Bashmakov *et al*., 2012). Our data is confirmed by the results of other authors. The investigations about the influence of organic and inorganic compounds for woody plants seedlings that leads to the growth activity increase (Pentelkina and Pentelkina, 2002; Ostroshenko and Ostroshenko, 2011), to the better development of oilseed radish seedlings (*Raphanus sativus* L. var. *oleiferus* Metzg.) (Nesterkina *et al*., 2019). The effect of seed treatment with growth stimulants were positive for corn and barley growing (Vasin *et al*., 2008, 2009), for soybean yield (Kadyrov and Schuchka, 2005) for sunflower (*Helianthus annuus* L.) morphological traits, yield components, grain yield and grain quality (Khodaei-Joghan *et al*., 2018).

Obtained results are consistent with earlier studies by R. G. Gafurov and co-workers on carbon N- and O-benzyl-containing compounds that have bright auxin activity, which is ensured by the presence of a benzyl group at the nitrogen or oxygen atom (Gafurov and Makhmutova, 2003, 2005). These compounds contain effector fragments that together determine the stress-protective activity, namely, the quaternary ammonium and benzyl groups and the hydroxyethyl group - an analog of the benzoxyethyl group (Budykina *et al*., 2005; Timeyko *et al*., 2005). Tested substances contain similar fragments, so they also show bright auxin activity. Based on the literature data (Budykina *et al*., 2005; Timeyko *et al*., 2005; Titov *et al*., 2011; Bashmakov *et al*., 2012) and the results of our research, it can be assumed that used compounds have the stress-protective activity for important vegetable culture – *Solanum melongena*. They can be accepted as growth stimulators.

4. CONCLUSIONS:

Compounds 2 and 5 were the most effective from the tested chemical substances. The compounds carry out the greatest stimulation of the growth processes and productivity of the common eggplant (*Solanum melongena* L.): 1,2,2,4-tetramethyl-6-(1-piperidinylcarbothioil)-1,2,3,4-tetrahydroquinoline hydrochloride and 4-[(1,2,2,4-tetramethyl-1,2-dihydro-6-quinolinyl)carbothioyl] -1-piperazinylcarbaldehyde hydrochloride in all tested concentrations. Compounds of the series 1-alkyl-2,2,4-trimethyl-6-aminocarbothioyl-1,2,3,4-tetrahydroquinoline at concentrations of 0.05 % and 0.1 % are effective. All tested compounds increase the plant height, length, width, the number of leaves, and the yield of common eggplant at a concentration of 0.1%. The synthesized chemical compounds cause stimulation of these characteristics compared with existing commercial preparations, for example, Epin-Extra. Compounds of the series 1-alkyl-2,2,4-trimethyl-6-aminocarbothioyl-1,2-dihydroquinoline and 1-alkyl-2,2,4-trimethyl-6-aminocarbothioyl-1,2,3,4-tetrahydroquinoline can be used as growth stimulants. They can increase the germination capacity of *Solanum melongena* seeds from 30 to 80 %, increase the vegetative mass from 10 to 40 %, and yield from 28 to 46 %. Thus, tetrahydroquinolines are most effective as stimulators of growth processes (and productivity) for common eggplant. Compounds containing a dihydro-6-quinolinyl substituent stimulate growth and also increase the yield of *Solanum melongena*.

5. ACKNOWLEDGMENTS:

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7. OPEN ACCESS

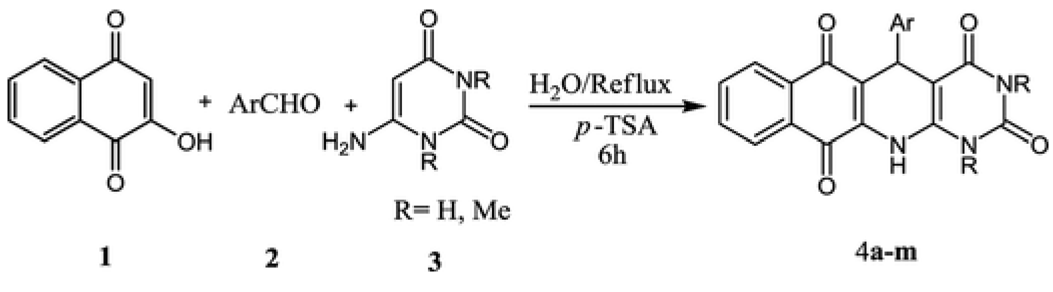

Figure 1. *The general scheme for the synthesis of pyrimido[4,5-b]quinoline-tetraones.*

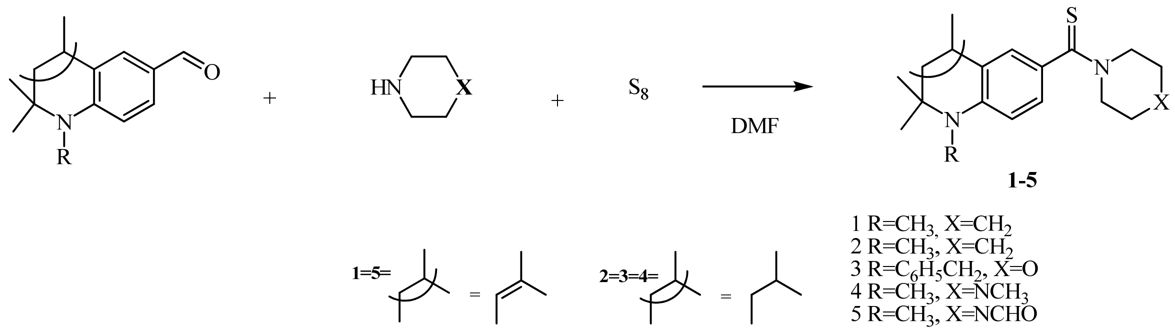

Figure 2. *The general scheme for the synthesis of 2,2,4-tetramethylhydroquinolin-6-ylcarbothioamides 1-5.*

Table 1. *The seed germination (in %) of Solanum melongena (cv. Black Beauty) treated with synthesized organic compounds*

Concentration	Control group	Epin group	compound 1	compound 2	compound 3	compound 4	compound 5
0,01%			33.3	61.1**[2]	77.8***[3]	62.2**[2]	47.8
0,05%	41.1	42.2	32.2	55.6*[1]	75.6***[3]	48.9	43.3
0,1%			31.1	54.4*[1]	73.3***[3]	46.7	42.2

Note for Table 1-6:

** – 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 group are reliable ($p<0.05$);

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

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

1,2,2,4-tetramethyl-6-(1-piperidinylcarbothioyl)-1,2-dihydroquinoline hydrochloride (compound 1);
1,2,2,4-tetramethyl-6-(1-piperidinylcarbothioyl) -1,2,3,4-tetrahydroquinoline hydrochloride (compound 2);
1-benzyl-2,2,4-trimethyl-6-(4-morpholinylcarbothioyl)-1,2,3,4-tetrahydroquinoline (compound 3);
1,2,2,4-tetramethyl-6-[(4-methyl-1-piperazinyl)carbothioyl]-1,2,3,4-tetrahydroquinoline hydrochloride (compound 4);
4-[(1,2,2,4-tetramethyl-1,2-dihydro-6-quinolinyl)carbothioyl]-1-piperazinylcarbaldehyde hydrochloride (compound 5).

Table 2. *The height (in cm) of Solanum melongena plant grown from seeds treated with synthesized chemical compounds*

Concentration	Control group	Epin group	compound 1	compound 2	compound 3	compound 4	compound 5
0.01%			6.4±0,1^{1}	8.1±0,2^{***3}	6.6±0,1	6.7±0.2	7.8±0.2^{***3}
80.05%	6.5±0,1	6.6±0,1	6.6±0,1	8.8±0,2^{***3}	7.6±0,1^{***3}	7.6±0.1^{***3}	8.8±0.2^{***3}
0.1%			7.4±0,1^{***2}	9.3±0,2^{***3}	8.6±0.1^{***3}	7.7±0.2^{***3}	9.0±0.1^{***3}

Table 3. *The leaf length (in cm) of Solanum melongena after treating the seeds with synthesized chemical compounds*

Concentration	Control group	Epin group	compound 1	compound 2	compound 3	compound 4	compound 5
0.01%			6.0±0,2	7.6±0,2^{***3}	6.4±0,1	6.4±0.1	7.6±0.2^{***3}
0.05%	6.3±0,1	6.4±0,1	6.5±0,1	8.7±0,2^{***3}	7.6±0,2^{***3}	7.5±0.1^{***3}	8.6±0.2^{***3}
0.1%			7.3±0,1^{***2}	9.0±0,2^{***3}	8.3±0.2^{***3}	7.6±0.1^{***3}	8.8±0.1^{***3}

Table 4. *The leaf width (in cm) of Solanum melongena after treating the seeds with synthesized chemical compounds*

Concentration	Control group	Epin group	compound 1	compound 2	compound 3	compound 4	compound 5
0.01%			4.8±0,2^{1}	5.7±0,1^{***3}	5.4±0,2	4.5±0.1	5.7±0.1^{***3}
0.05%	4.5±0,1	4.6±0,1	5.1±0,1	6.4±0,1^{***3}	6.0±0,2^{***3}	5.0±0.1^{***3}	6.3±0.2^{***3}
0.1%			5.6±0,1^{***2}	6.7±0,1^{***3}	6.3±0.1^{***3}	5.2±0.1^{***3}	6.8±0.2^{***3}

Table 5. *The number of leaves of Solanum melongena after treating the seeds with synthesized chemical compounds*

Concentration	Control group	Epin group	compound 1	compound 2	compound 3	compound 4	compound 5
0.01%			5.4±0,2^{*1}	5.6±0,2**	5.4±0,1^{*1}	5.4±0.2^{*1}	5.3±0.1^{1}
0.05%	5.2±0,1	5.6±0,2**	5.6±0,2**	6.5±0,2^{***3}	5.6±0,2**	5.6±0.2**	5.8±0.1^{**1}
0.1%			5.7±0,2**	6.7±0,2^{***3}	5.7±0.2**	5.8±0.2^{**1}	5.8±0.1^{**1}

Table 6. *The yield (in kg/m^2) of Solanum melongena plant grown from seeds treated with synthesized chemical compounds*

Concentration	Control group	Epin group	compound 1	compound 2	compound 3	compound 4	compound 5
0.01%	3.2±0,1	3.3±0,1	3.5±0,1	5.1±0,1^{**2}	4.2±0,2^{*1}	4.5±0.1^{**2}	5.3±0.1^{**2}
0.05%			4.1±0,1^{*1}	5.4±0,1^{***3}	4.4±0,2^{**2}	4.8±0.1^{**2}	5.5±0.2^{***3}
0.1%			4.6±0,1^{**2}	5.6±0,1^{***3}	4.6±0.1^{**2}	4.8±0.1^{**2}	5.7±0.2^{***3}