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Growth-regulatory Activity of 2-Methyl-4-thioquinoline Derivatives

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At the current moment, in order to increase the crop yield and improve the quality of food, pharmaceutical, industrial and energy products, a search for novel environmentally friendly plant treatment agents is given a top priority. Hence the task of finding chemical regulators and stimulators of plant growth that would alter the developmental cycle of crops most effectively at the lowest toxicity level is of utmost relevance.

While studying the cytotoxic effects of plant treatment agents on sprouts of plants belonging to the *Cucumis genus*, a quinoline derivative (a compound under the **KM-38** laboratory code) was observed to have a significant stimulating effect, which became a prerequisite for the in-depth studies that followed. The paper presents the results of laboratory studies of the effect of quinoline derivatives on monocotyledonous (soft winter wheat (*Triticum aestivum L.*)) and dicotyledonous (cultivated soybean (*Glycine max (L.) Merrill*)) plants. In order to assess its activity, the growth-regulating effect of **KM-61** compound, which has a structure similar to that of main heteroauxins (indole-3-acetic acid), was investigated. The activity of compounds was examined on the basis of seed samples of soft winter wheat («Zemlyachka», «Kiriya», «Selyanka», «Kosovytsia», «Vdala») and soybean («Masha», «Opheliya», «Sedmytsia», «Sprynt», «Sharm») cultivars.

The results of the studies confirmed the existence of growth-stimulating properties of the investigated compounds. Sprouts of monocotyledonous and dicotyledonous plants have different sensitivity to the activity of the growth regulators. **KM-61** compound appears to be more efficient with regard to soft winter wheat sprouts. It caused the increase in the growth of the root system, which varied depending on a given cultivar and a concentration of the chemical agent, of up to 49% (19% in the case of a plant's hypocotyl). **KM-38** compound showed a moderate effect on the cultivars of soft winter wheat under study. The biggest impact on the growth of soybean sprouts came from **KM-38** plant treatment agent (stem length increased up to 50%, and the root – up to 30%), the greatest effect being noticeable with regard to the «Sharm» and «Opheliya» cultivars. It should be noted that the selected compounds exhibit low toxicity when dealing with warm-blooded animals and are capable of growth-stimulating activity even at very low concentrations (0.001-0.00005%). The obtained results show considerable promise regarding a further study of the aforementioned compounds in the direction of discovering new types of growth stimulants.

Keywords: quinoline derivatives; growth-regulatory activity; wheat; soybean

Introduction

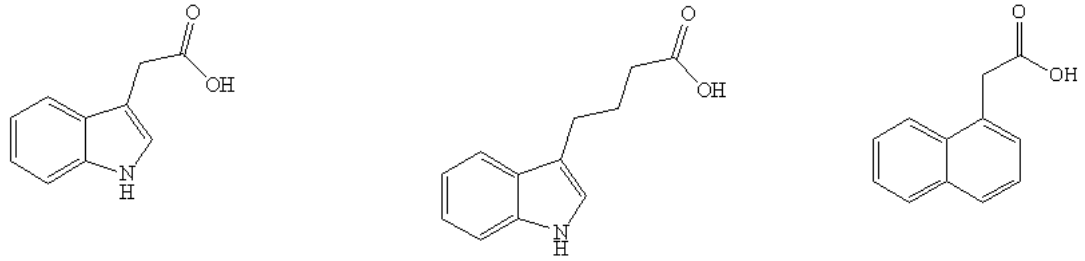
The search for new types of environmentally friendly plant treatment agents is steadily carried out in order to increase the productivity of crops and improve the quality of food, pharmaceutical, industrial, and energy products. These include plant's growth regulators – natural or synthetic compounds used for the purpose of presowing seed treatment and/or treatment of terrestrial plant organs during the growing season to control their growth and development, improve product quality and increase crop yields. Plant treatment agents of natural origin are generally safer whereas the synthetic ones are cheaper. Therefore, it is important to look for chemical compounds that are able to act as plant growth stimulants, which retain their effectiveness while simultaneously exhibiting low toxicity levels (Bylina et al., 2010; Mikhed'kina et al., 2019).

Normal plant development depends on a number of external and internal factors. External (natural) ones, such as light, temperature, daylight hours, etc., cannot be altered by human intervention, whereas internal factors that regulate growth and development are chemical in nature and are thus the subject of scientists' attention. Examples of endogenous factors are plant hormones (auxins, gibberellins, cytokinins), which appear active even in small concentrations. Phytohormones have both inhibitory and stimulating effects and can be regarded as chemical regulators (Makrushin et al., 2006).

Synthetic plant treatment agents that are either a modification of natural compounds or contain structurally similar fragments can be considered the most promising ones. Examples of such plant growth regulators of synthetic origin that are available on the market are Ivine, which contains the corresponding active substance N-oxide of 2,6-dimethylpyridine; Poteitin – a complex of 2,6-dimethylpyridine N-oxide and sodium succinate; Emistim C is a complex of phytohormones of the fuchsine and cytokinin nature, amino-acids, carbohydrates, fatty acids and trace elements (Romanyuk et al., 2002; Gut, 2011). The works of (Kornet et al., 2007; Kornet, 2012; Petrusha, 2013; Derevyanko et al., 2016; Zandona Renan Ricardo et al., 2019) showcase the stimulating effect of pyrrole analogues of chalcone compounds; test the cytotoxicity of a number of quinoline derivatives and the growth-stimulating

effect of pyridine derivatives. The stimulating effect of solutions of salts of a number of pyrrole analogues of chalcone on germination energy, germination, and biometric parameters of barley seeds of various cultivars and of rye of «Dihar» winter cultivar has also been studied. It has been determined that the most effective compounds that act as growth stimulants are arylpropenoylpyrrole carboxylic acids with methoxy- and bromine in the phenyl nucleus (Gut, 2011). Zandona Renan Ricardo, Pazdiora Paulo Cesar, Pazini Juliano de Bastos, Seidel Enio Junior, Ethur Luciana Zago (Zandona Renan Ricardo et al., 2019) proved the effectiveness of altering soybean development by treating their seeds using a combination of fungicides (fludiostonil) and biological agents, thereby increasing the crop yields.

Previous studies have shown the viability of 2-methyl-4-thioquinoline derivatives as potential effective regulators of plant growth and of their development cycle. In particular, while studying cytotoxicity using the sprouts of plants belonging to the *Cucumis genus* as a test subject, a significant stimulating effect of quinoline thioderivatives (**KM-38** and **KM-61** compounds) has been observed (Kornet, 2012). These substances are similar in structure (containing a heteroaromatic moiety and an aliphatic acid residue) to the structures of main heteroauxins (indole-3-acetic, indole-3-butyric, α-naphthylacetic acids, Figure 1 a, b, c) and potent even at very low concentrations (0.001% - 0.00005%) without being heavily toxic to warm-blooded animals (Kornet, 2012).



a **b** **c**

Figure 1. Structural formulas of indole-3-acetic (a), indole-3-butyric (b), α-naphthylacetic acids (c)

The aim of this work was to study the growth-stimulating effect of the most promising 2-methyl-4-thioquinoline derivatives in laboratory conditions on monocotyledonous and dicotyledonous plants.

Methods

Laboratory experiments were conducted in the laboratory of biotechnology of physiologically active substances of Zaporizhzhia National University. To assess the biological activity of 2-methyl-4-thioquinoline derivatives (**KM-38** and **KM-61** compounds) the following biological test subjects were used: soft winter wheat (*Triticum aestivum* L.) and cultivated soybean (*Glycine max*, (L.)) *Merr*.). The activity of the chemical compounds was studied on the basis of seed samples of soft winter wheat («Zemlyachka», «Kiriya», «Selyanka», «Kosovytsia», «Vdala») and soybean («Masha», «Opheliya», «Sedmytsia», «Sprint», «Sharm») cultivars. The seeds were germinated in Petri dishes using strips of filter paper for constant and uniform humidification. Dry seeds were placed in Petri dishes in strips of 25 seeds for soft winter wheat and 20 seeds for soybean at a distance of 0.5-1.5 cm from each other. 10 ml of aqueous solutions of compounds at concentrations of 5, 20, 100 μg/ml were added and incubated for 7 days at 25°C in the dark. Experiments were repeated three times in total. After incubation, seed germination and biometric characteristics of sprouts were determined. Sprouts obtained from seeds germinated in distilled water served as controls.

Seeds germinated in a laboratory as well as properly formed sprouts were determined in accordance with the requirements (DSTU 4138-2002). 30-50 seeds of the indicator plant have been planted in total.

Results and Discussion

The results of the experiments indicate that the investigated chemical compounds (**KM-38** and **KM-61**), mainly have a positive effect on the processes of initial growth of soft winter wheat (*Triticum aestivum L.*) (Figures 3 and 4) and soybeans (*Glycine max, (L.) Merr*.) (Figures 4 and 5). Their effect is manifested in stimulating the growth of roots and stems of shoots. The physiological activity of the compounds depends on the chemical structure and the specifics of the cultivars, namely, the initial viability of the seeds of monocotyledonous and dicotyledonous plants.

Winter wheat and soybeans reacted differently to the action of chemical compounds (**KM-38** and **KM-61**). The root system of soft winter wheat sprouts has been developing more intensely (Figures 2 and 3). In soybean sprouts, the growth of the above-ground part of the plant proved to be most substantial (Figures 4 and 5). Chemical substances significantly affected the increase in soybean root length, but there was a slight decrease in the weight of the root system compared to the control (plants grown in distilled water).

The stimulating activity of the chemical substances under study largely depended on the concentration of their solutions. In most cases, the growth-promoting activity of the compounds was higher at concentrations of 20 μg/ml and 100 μg/ml. At the same time, biometric indicators increased to a greater extent compared to the germination energy and germination potential. The low concentration of compounds (5 μg/ml) had a weak stimulating effect on both soft winter wheat seeds and soybean seeds.

KM-38 compound, which has a mercaptopropionic acid residue in its structure and a methoxygroup in the 6-position of quinoline, showed a moderate effect on soft winter wheat (Figure 2). The increase in root length and hypocotyl length of wheat seedlings, when treated with the compound, ranged from about 2% to 43% and from about 2% to 9%, respectively. The **KM-38** compound stimulated root growth most heavily in such cultivars as «Vdala» (100 μg/ml), «Kiriya» (20 mg ml and 100 μg/ml), «Selyanka» (5 μg/ml and 100 μg/ml). However, in the case of «Vdala» (5 μg/ml) and «Kiriya» (5 μg/ml) cultivars, **KM-38** suppressed the biometric parameters of hypocotyl compared with the control (Figure 2).

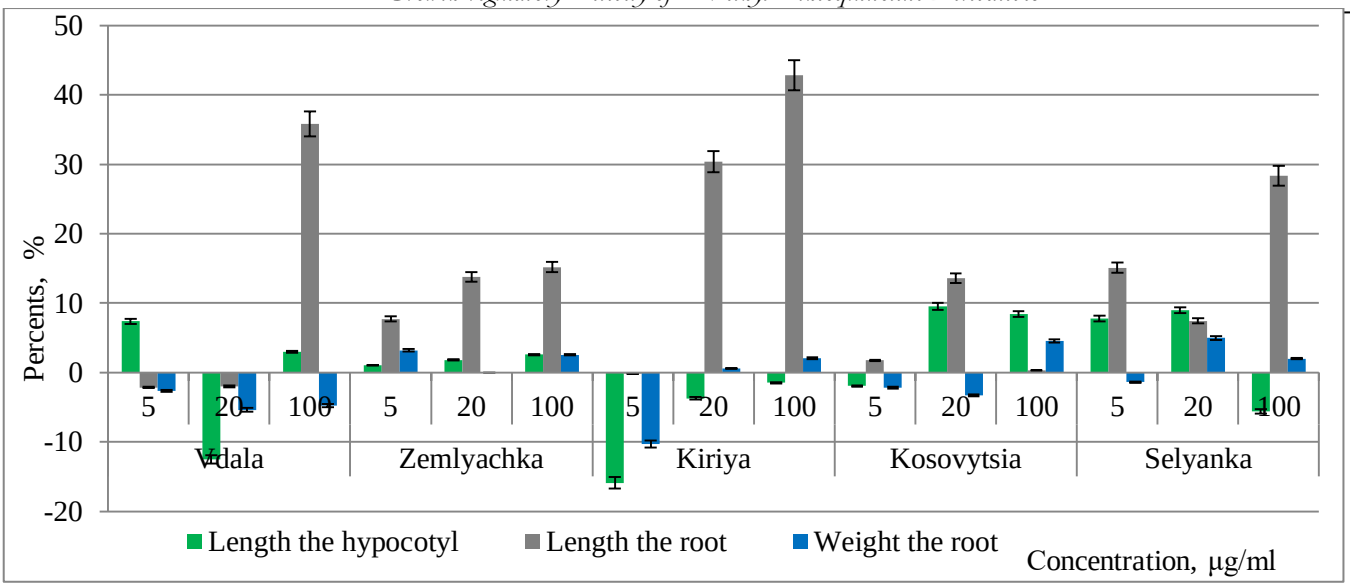


Figure 2. The effect of **KM-38** on the biometric characteristics of soft winter wheat sprouts (*Triticum aestivum* L.).

The growth of soft winter wheat sprouts was most significantly influenced by the **KM-61** compound, which has a similar structure to indole-3-acetic acid: an increase in the length of the root system from 5% to 49% and a slight increase in the length of the hypocotyl from 1% to 19% (Figure 3). «Kiriya» soft winter wheat cultivar (20 µg/ml and 100 µg/ml) and «Selyanka» (5 µg/ml, 20 µg/ml and 100 µg/ml) saw a more noticeable effect in root system growth reaching 15-45%; however, at certain concentrations, there was a moderate inhibitory effect (by 3%-14%) of the **KM-61** compound on the length of the hypocotyl of «Vdala» (all concentrations); «Zemlyachka» (20 µg/ml and 100 µg/ml) «Kiriya» (5 µg/ml and 20 µg/ml) soft winter wheat cultivars (Figure 3).

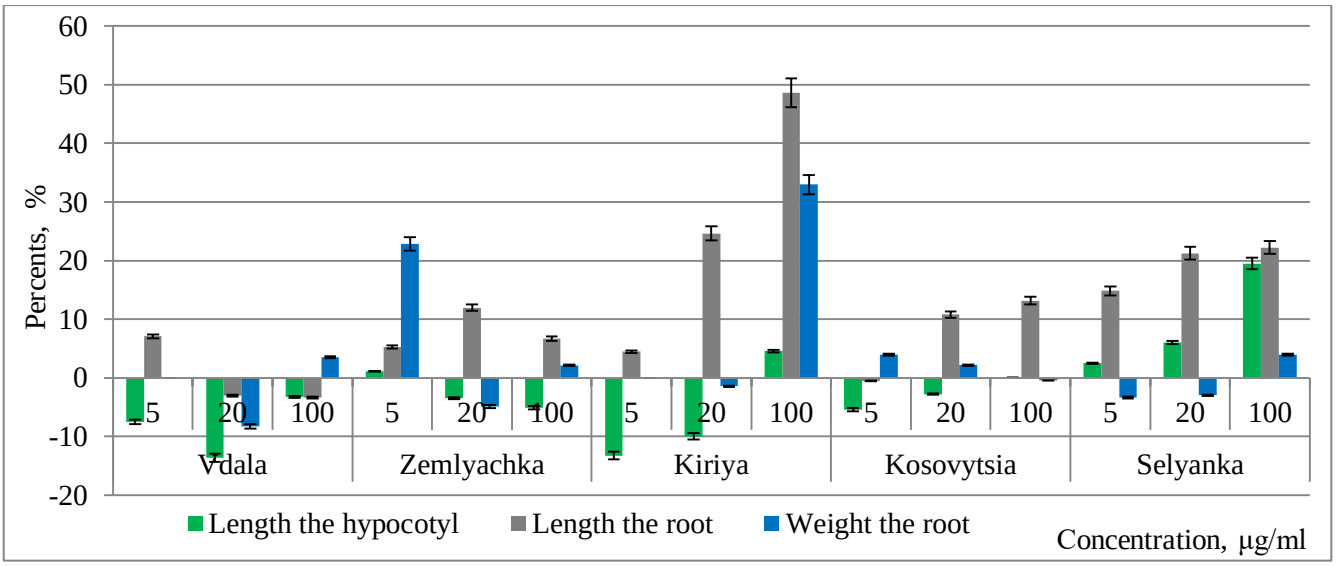


Figure 3. The effect of **KM-61** on the biometric characteristics of soft winter wheat sprouts (*Triticum aestivum* L.).

Soybean sprouts responded best to the **KM-38** plant treatment agent (Figure 4). This is evidenced by an increase in root length from 28% to 30% and stem length from 22% to 50% in «Opheliya» and «Sharm» soybean cultivars, respectively. At concentrations of 20 and 100 µg/ml in all soybean cultivars, there was a decrease in root weight by 5-28% (Figure 4).

Less noticeable effect on cultivated soybean sprouts was observed under the influence of **KM-61** compound, despite the structural similarity with the heteroauxin phytohormone (Figure 5). At a concentration of 5 µg/ml «Opheliya» and «Sedmytsia» soybean cultivars saw an increase in the length of both root and stem. But there has been an inhibitory effect on biometric characteristics of the root in the case of «Masha» soybean cultivar, while in the case of «Sprint» and «Sharm» soybean cultivars the growth-stimulating effect has been insignificant (Figure 5).

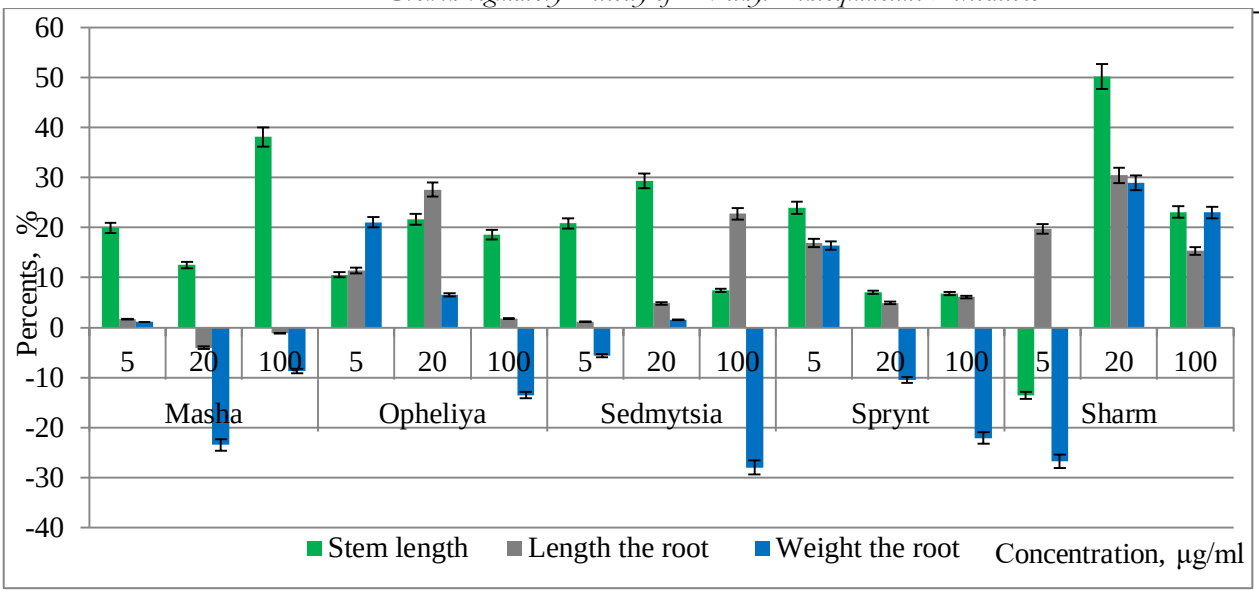


Figure 4. Influence of KM-38 compound on biometric characteristics of soybean sprouts (*Glycine max*, (L.) *Merr.*).

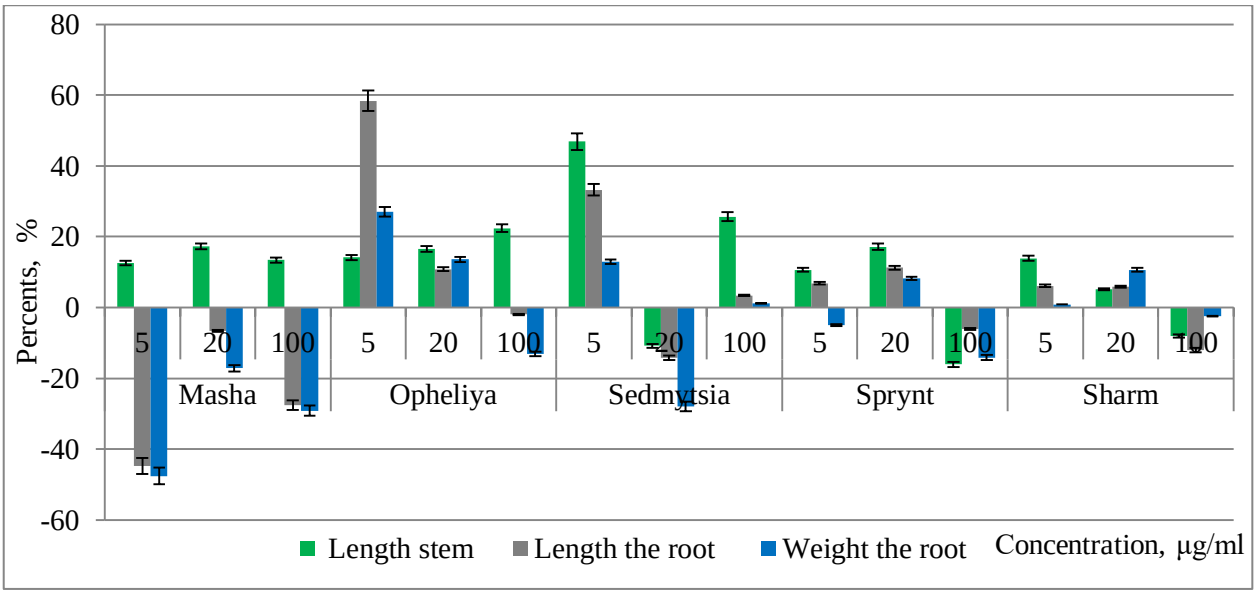


Figure 5. Influence of KM-61 compound on biometric characteristics of soybean sprouts (*Glycine max*, (L.) *Merr.*).

Conclusion

Thus, we have shown that the investigated chemical compounds (**KM-38** and **KM-61**) have growth-stimulating properties. Sprouts of monocotyledonous and dicotyledonous plants all respond differently to the activity of the growth regulators under study. The best results in relation to sprouts of soft winter wheat can be attributed to the **KM-61** compound, which has a similar structure to indole-3-acetic acid: there was an increase in the length of the root system of up to 49%, the length of the hypocotyl of up to 19%, while the strongest effect on the growth of the root system was observed in the case of «Kiriya» and «Vdala» cultivars. **KM-38** compound showed a moderate effect on soft winter wheat sprouts.

The **KM-38** plant treatment agent had the greatest effect on the soybean sprouts belonging to the «Sharm» and «Opheliya» cultivars, such as an increase in stem length by 7-50% and root length of up to 30%, in particular.

The obtained results show considerable promise regarding a further study of the aforementioned compounds in the direction of discovering new types of environmentally friendly growth stimulants.

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