BIOLOGICAL SCIENCES

NEW GROWTH REGULATORS OF BARLEY BASED ON PYRIMIDINE AND PYRIDINE DERIVATIVES

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ABSTRACT

This work is devoted to the screening for new effective plant growth regulators based on synthetic compounds, pyrimidine and pyridine derivatives. Study of the plant growth-regulating activity of synthetic compounds was carried out on spring barley (Hordeum vulgare L.) variety Avatar. The effect of synthetic compounds on the morphometric parameters of barley plants grown in laboratory conditions was studied. The plant growth-regulating activity of synthetic compounds was compared with the plant growth-regulating activity of phytohormones auxins IAA (1H-indol-3-yl)acetic acid) and NAA (1-naphthylacetic acid). The most biologically active synthetic compounds were selected, which show plant growth-regulating activity, similar to or exceeding the activity of auxins IAA and NAA. The highest parameters of the average length of the shoots, which exceeded similar parameters of control plants by 13.73 - 24.06 %, were obtained on 2-week-old barley plants treated with synthetic compounds, derivatives of sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur and Kamethur), 6-methyl-2-propylsulfanyl-pyrimidin-4-ol, 2-benzylsulfanyl-6-methylpyrimidin-4-ol, and sodium 4-hydroxypyrimidine--2-thiolate, respectively. The highest parameters of the average length of the roots, which exceeded similar parameters of control plants by 66.67 – 121.35 %, were obtained on 2-week-old barley plants treated with synthetic compounds, derivatives of N-oxide-2,6-dimethylpyridine (Ivin), sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur and Kamethur), 2-ethylsulfanyl-6-methylpyrimidin-4-ol, and 6-methyl-2-propylsulfanyl-pyrimidin-4-ol, respectively. The highest parameters of the average biomass of 10 plants, which exceeded similar parameters of control plants by 30.59 – 86.46 %, were obtained on 2-week-old barley plants treated with synthetic compounds, derivatives of N-oxide-2,6-dimethylpyridine (Ivin), sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur and Kamethur), 6-methyl-2-propylsulfanyl-pyrimidin-4-ol, and sodium 4-hydroxypyrimidine--2-thiolate, respectively. A comparative analysis of the growth-regulating activity of auxins showed that the morphometric parameters obtained on 2-week-old barley plants treated with IAA and NAA, exceeded similar parameters of control plants, as follows: plant shoot length by – 7.51 - 20.57 %, plant root length – by 15.45-32.81 %, plant biomass – by 39.59 – 49.01 %, respectively. It was shown that pyrimidine and pyridine derivatives at a concentration of 10^{-7}M exhibit cytokinin-like activity in increasing the content of photosynthetic pigments in the leaves of barley plants. The content of chlorophyll a increased by 6.46 - 68.33%, chlorophyll b increased by 6.2 - 64.11%, chlorophyll a+b increased by 6.37 - 66.81%, carotenoids increased by 2.65 - 29.81%, respectively, compared with similar parameters of control barley plants treated with distilled water. The practical use of the synthetic compounds, pyrimidine and pyridine derivatives: Methyur, Kamethur, Ivin, and other selected most active synthetic compounds for improving the development of shoots and roots, increasing the biomass of spring barley (Hordeum vulgare L.) variety Avatar in the vegetative phase, and increasing the content of photosynthetic pigments in plant leaves is proposed.

Keywords: Hordeum vulgare L., auxins, plant growth regulators, pyrimidine, pyridine.

Introduction.

Barley (*Hordeum vulgare* L.) is one of the important food and fodder crops [1]. Barley grain is close to corn grain in terms of nutrients (carbohydrates, proteins, calcium, phosphorus, vitamins) [1]. About 80 % of the barley grain grown in the United States is used for beer production, 14 % is used for the production of distilled alcohol, and 6 % is used for the production of malt syrup, sweet milk, and human food such as cereal flour [1-3]. Barley is used in the food and pharmaceutical industry for the production of glucose, maltose syrups and beta-amylase due to the high content of starch in the grain [1]. Beta-glucans extracted from barley grain or its bran can be used as thickeners in food products, industrial hydrocolloids and pharmaceuticals [1]. Barley grain can also be used as a major source of energy, protein and fiber for ruminants, and a major source of energy and protein for pigs [1].

In Ukraine, as well as in other countries of the world, many economically important varieties of barley have been created, which can fully ensure the production of food and fodder grains and brewing raw materials. Modern varieties of barley are capable of producing high yields, and with additional fertilization, the yield of this crop can be increased to 40 t/ha, as has been achieved in European countries [1, 4, 5]. In recent years, intensive barley cultivation technologies based on the practical application of plant growth regulators have attracted considerable attention [6 - 8]. However, the creation of new efficient and environmentally friendly growth regulators of barley is a priority task for the successfully development of the modern agricultural sector in economically developed countries.

Currently, the screening for new effective synthetic compounds capable of exibiting biological activity similar to natural plant hormones to increase the productivity of barley and its resistance to stress factors is very relevant. At is known, plant hormones auxins play a key role in the regulation of plant growth and development throughout ontogeny [9, 10]. In agricultural biotechnology, both natural auxin such as IAA (1*H*-Indol-3-ylacetic acid) and its synthetic analogue, such as NAA (1-Naphthylacetic acid), are widely used to stimulate the organogenesis of barley roots and shoots [8, 11, 12]. At the same time, plant physiologists are searching for new synthetic analogs of auxins that have a growth-regulating effect similar to that of auxins at low concentrations, nontoxic to human and animal health. Among such compounds, the most promising are synthetic compounds, derivatives of pyridine and pyrimidine, which are widely used in agriculture as plant growth regulators and herbicides [13 - 17].

Today the new effective and environmentally friendly plant growth regulators based on pyrimidine and pyridine derivatives are synthesized in V.P. Kukhar Institute of Bioorganic Chemistry and Petrochemistry of National Academy of Sciences of Ukraine. The most known new plant growth regulators based on pyrimidine and pyridine derivatives are Methyur (sodium salt of 6-methyl-2-mercapto-4-hydroxypyrimidine), Kamethur (potassium salt of 6-methyl-2-mercapto-4-hydroxypyrimidine) and Ivin (N-oxide-2,6-dimethylpyridine). Our earlier studies have proved their practical application for intensifying the growth and development of various agricultural, industrial, horticultural and floricultural crops, increasing their productivity, and improving the adaptation of crops to stress factors [18 - 25]. These new synthetic plant growth regulators exhibit high growth-regulating activity when used at low, non-toxic to human and animal health concentrations ranging from 10^{-5}M to 10^{-8}M. Recently we have been searching for new physiologically active compounds among synthetic pyridine and pyrimidine derivatives that have growth-regulating activity on various crops [26 - 35].

The aim of this work is screening of new effective plant growth regulators of spring barley (*Hordeum vulgare* L.) variety Avatar based on synthetic compounds, pyrimidine and pyridine derivatives.

Materials and methods.

Chemical structure of plant hormones auxins IAA, NAA, and synthetic compounds, pyrimidine and pyridine derivatives.

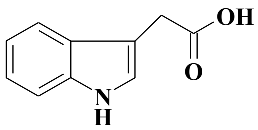
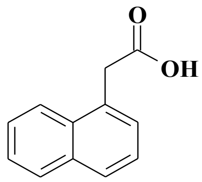
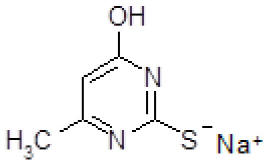
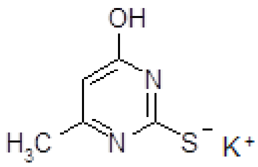
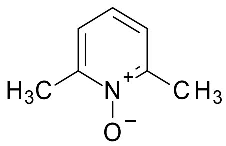
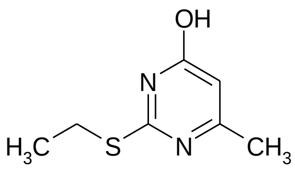
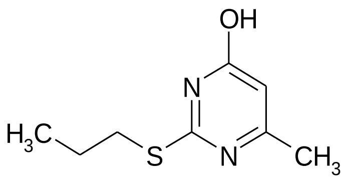
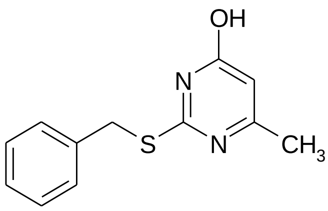
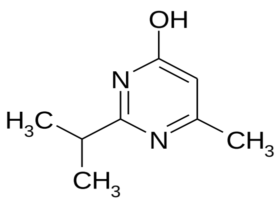
Synthetic compounds, derivatives of pyrimidine and pyridine were synthesized in the Department for Chemistry of Bioactive Nitrogen-Containing Heterocyclic Compounds, V.P. Kukhar Institute of Bioorganic Chemistry and Petrochemistry of the National Academy of Sciences of Ukraine.

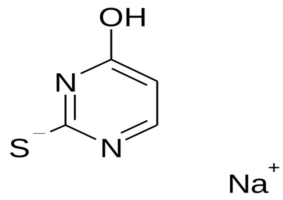
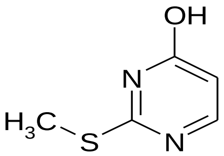
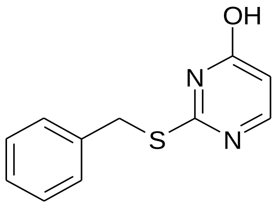
The plant growth-regulating activity of synthetic compounds, pyrimidine and pyridine derivatives was compared with the activity of phytohormones auxins IAA (1*H*-indol-3-yl)acetic acid) and NAA (1-naphthylacetic acid) manufactured by Sigma-Aldrich, USA. Synthetic pyrimidine and pyridine derivatives and phytohormones IAA and NAA were used in a concentration of 10^{-7}M.

Chemical structure of plant hormones auxins IAA, NAA, and synthetic compounds, pyrimidine and pyridine derivatives used in the experiments is given in Table 1.

Table 1

Chemical name, structure and relative molecular weight of auxins IAA, NAA, and compounds, pyrimidine and pyridine derivatives

Chemical compound №	Chemical structure	Chemical name and relative molecular weight (g/mol)
IAA		1H-Indol-3-ylacetic acid MW=175.19
NAA		1-naphthylacetic acid MW=186.21
Methyur		Sodium salt of 6-methyl-2-mercapto-4-hydroxypyrimidine MW=165.17
Kamethur		Potassium salt of 6-methyl-2-mercapto-4-hydroxypyrimidine MW=181.28
Ivin		N-oxide-2,6-dimethylpyridine MW=125.17
1		2-ethylsulfanyl-6-methylpyrimidin-4-ol MW=170.23
2		6-methyl-2-propylsulfanyl-pyrimidin-4-ol MW=184.26
3		2-benzylsulfanyl-6-methylpyrimidin-4-ol MW=232.31
4		2-isopropyl-6-methyl-pyrimidin-4-ol MW=152.20

5		Sodium salt of 4-hydroxypyrimidine-2-thiolate MW=149.14
6		2-methylsulfanylpyrimidin-4-ol MW=142.18
7		2-benzylsulfanylpyrimidin-4-ol MW=218.28

Plant growing conditions.

The plant growth-regulating activity of auxins IAA, NAA, and synthetic compounds, pyrimidine and pyrimidine derivatives was studied. For this, the seeds of spring barley (*Hordeum vulgare* L.) variety Avatar were sterilized with 1% KMnO4 solution for 3 min, then treated with 96 % ethanol solution for 1 min, after which they were washed three times with sterile distilled water. After this procedure, barley seeds were placed in cuvettes (each with 20 - 25 seeds) in perlite moistened with distilled water (control), or water solutions of auxins IAA and NAA, or synthetic compounds, pyrimidine and pyridine derivatives at a concentration of 10^{-7}M. Then the treated seeds were placed in a thermostat for germination in the dark at a temperature of 22°C for 48 hours. The germinated seeds were placed in a climate chamber, where barley plants were grown for 2 weeks in a 16/8 light/dark mode, at a temperature of 20 – 22 °C, illumination of 3000 lux, and an air humidity of 60-80%. Comparative analysis of morphometric parameters of barley plants (average length of shoots and roots (mm), average biomass of 10 plants (g)) was carried out at the end of a two-week period according to the procedure [36].

Determination of the content of photosynthetic pigments in plant leaves.

To perform the extraction of photosynthetic pigments we homogenized a sample (500 mg) of plant leaves in the porcelain mortar in a cooled at the temperature 10 °C 96 % ethanol at the ratio of 1: 10 (weight: volume) with addition of 0,1-0,2 g CaCO3 (to neutralize the plant acids). The 1 ml of obtained homogenate was centrifuged at 8000 g in a refrigerated centrifuge K24D (MLW, Engelsdorf, Germany) during 5 min at the temperature 4 °C. The obtained precipitate was washed three times, with 1 ml 96 % ethanol and centrifuged at above mentioned conditions. After this procedure, the optical density of chlorophyll a, chlorophyll b and carotenoid in the obtained extract was measured using spectrophotometer Specord M-40 (Carl Zeiss, Germany).

The content of chlorophyll a, chlorophyll b, and carotenoids was calculated in accordance with formula [38, 39]:

Cchl a = 13.36×A664.2 – 5.19×A648.6,
Cchl b = 27.43×A648.6 – 8.12A×664.2,
Cchl (a + b) = 5.24×A664.2 + 22.24×A648.6,
Ccar = (1000×A470 – 2.13×Cchl a – 97.64×Cchlb)/209,

Where,

Cchl – concentration of chlorophylls (μg/ml), Cchl a – concentration of chlorophyll a (μg/ml), Cchl b – concentration of chlorophyll b (μg/ml), Ccar – concentration of carotenoids (μg/ml), A – absorbance value at a proper wavelength in nm.

The chlorophyll and carotenoids content per 1 g of fresh weight (FW) of extracted from plant leaves was calculated by the following formula (separately for chlorophyll a, chlorophyll b and carotenoids):

$A_1=(C\times V)/(1000\times a_1)$,

Where, A_1 – content of chlorophyll a, chlorophyll b, or carotenoids (mg/g FW),

C - concentration of pigments (μg/ml),

V - volume of extract (ml),

a_1 - sample of plant tissue (g).

The content of chlorophyll a, chlorophyll b, and carotenoids (%) determined in the leaves of the experimental plants grown in the water solution of auxins IAA and NAA, or synthetic compounds, pyrimidine and pyrimidine derivatives at a concentration of 10^{-7}M was calculated in accordance with similar indices determined in the leaves of control plants grown in the distilled water.

Statistical processing of the experimental data, performed in triplicate, was carried out according to the Student's t-test with a significance level of $P \leq 0.05$; mean values ± standard deviation (± SD) [37].

Results and Discussion.

Study of plant growth-regulating activity of synthetic compounds, derivatives of pyrimidine and pyridine.

Our previous studies showed the feasibility of using new synthetic compounds, derivatives of pyrimidine and pyridine: Methyur, Kamethur and Ivin to improve the morphometric parameters of winter barley (*Hordeum vulgare* L.) variety Svetozar, as well as to increase the content of the main indicators of productivity - photosynthetic pigments and total soluble protein in plant leaves [20].

In these studies, it was shown that the morphometric parameters of 6-week-old barley plants treated with synthetic compounds, derivatives of pyrimidine and pyridine: Methyur, Kamethur and Ivin, applied at a concentration of 10^{-8}M, exceeded similar parameters of control barley plants treated with distilled water, as follows: by the length of the shoots - by 13 – 21 %, by the length of the roots - by 25 - 84 %, by the number of roots - by 9 – 14 %, by the biomass of plants - by 21 – 52 %, respectively [20].

The conducted studies also proved a positive effect of the synthetic compounds, derivatives of pyrimidine and pyridine: Methyur, Kamethur and Ivin, which were used to treat barley seeds at a concentration of 10^{-8}M, on increasing the content of photosynthetic pigments in barley leaves: chlorophylls a+b - by 38 – 61 %, chlorophyll a - by 25 – 36 %, chlorophyll b - by 62 – 108 %, carotenoids - by 5 – 6 %, as well as the content of total soluble protein - by 3 – 15 %, respectively, compared to similar indicators of control barley plants treated with distilled water [20].

Based on the data of our previous studies of the plant growth-regulating activity of synthetic compounds, derivatives of pyrimidine and pyridine: Methyur, Kamethur and Ivin on winter barley (*Hordeum vulgare* L.) variety Svetozar, it is very relevant to study the growth-regulating activity of these compounds, as well as new synthetic compounds, derivatives of pyrimidine on spring barley (*Hordeum vulgare* L.) variety Avatar.

The study of the plant growth-regulating activity of synthetic compounds, derivatives of pyrimidine and pyridine (listed in Table 1) showed that they exhibit an effect similar to auxins IAA and NAA when used to treat barley seeds at a concentration of 10^{-7}M. Improvement of growth and development of roots and shoots of spring barley (*Hordeum vulgare* L.) variety Avatar was observed for 2 weeks (Fig. 1).

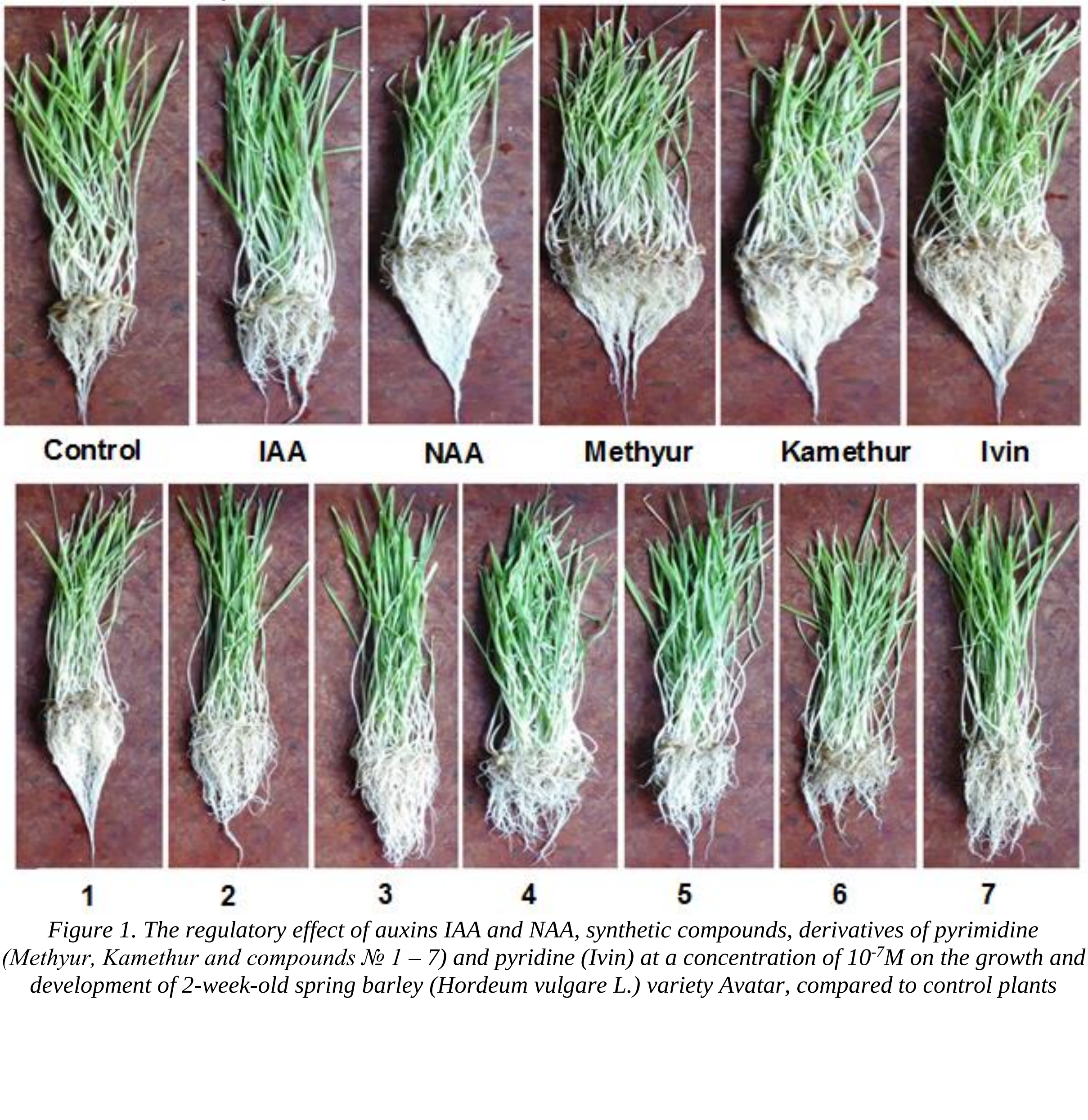


Figure 1. The regulatory effect of auxins IAA and NAA, synthetic compounds, derivatives of pyrimidine (Methyur, Kamethur and compounds № 1 – 7) and pyridine (Ivin) at a concentration of 10^{-7}M on the growth and development of 2-week-old spring barley (Hordeum vulgare L.) variety Avatar, compared to control plants

Statistical analysis of the morphometric parameters of 2-week-old barley showed that the highest parameters of the average length of the shoots (mm), which exceeded the similar parameters of control plants by 13.73 - 24.06 %, were obtained on barley plants treated with synthetic compounds, derivatives of sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur and Kamethur), compound № 2 - 6-methyl-2-propylsulfanyl-pyrimidin-4-ol, compound № 3 - 2-benzylsulfanyl-6-methylpyrimidin-4-ol and compound № 5 -sodium 4-hydroxypyrimidine--2-thiolate, respectively (Fig. 2).

The parameters of the average length of the shoots (mm) of barley plants increased as follows: by 24.06 % - after treatment with Methyur, by 13.73 % - after treatment with Kamethur, by 17.27 – 22.64 % - after treatment with synthetic compounds № 2, 3 and 5, respectively, compared with similar parameters of control barley plants treated with distilled water (Fig. 2).

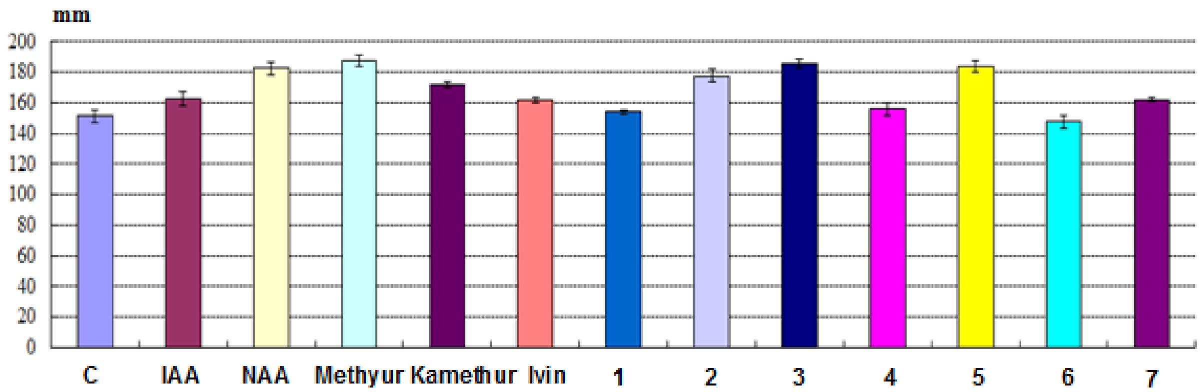


Figure 2. The regulatory effect of auxins IAA and NAA, synthetic compounds, derivatives of pyrimidine (Methyur, Kamethur and compounds № 1 – 7) and pyridine (Ivin) at a concentration of 10^{-7}M on an average length of the shoots (mm) of 2-week-old spring barley (Hordeum vulgare L.) variety Avatar, compared to control plants (C)

At the same time, N-oxide-2,6-dimethylpyridine (Ivin) and synthetic compounds № 1, 4 and 7 showed lower growth-regulating activity; the average length of the shoots (mm) of barley plants increased as follows: by 6.65 % - after treatment with Ivin and by 1.75 – 7.03 % - after treatment with synthetic compounds № 1, 4 and 7, respectively, compared with similar parameters of control barley plants treated with distilled water (Fig. 2).

A comparative analysis of the growth-regulating activity of auxins showed that the parameters of the average length of the shoots (mm) of barley plants increased as follows: by 7.51 % - after treatment with IAA, and by 20.57 % - after treatment with NAA, respectively, compared with similar parameters of control barley plants treated with distilled water (Fig. 2).

The highest parameters of the average length of the roots (mm), which exceeded similar parameters of control plants by 66.67 – 121.35 %, were obtained on 2-week-old barley plants treated with synthetic compounds, derivatives of N-oxide-2,6-dimethylpyridine (Ivin), sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur and Kamethur), compound № 1 - 2-ethylsulfanyl-6-methylpyrimidin-4-ol, and compound № 2 - 6-methyl-2-propylsulfanyl-pyrimidin-4-ol, respectively (Fig. 3).

The parameters of the average length of the roots (mm) of barley plants increased as follows: by 113.54 % - after treatment with Ivin, by 121.35 % - after treatment with Methyur, by 107.59 % - after treatment with Kamethur, by 66.67 – 89.5 % - after treatment with synthetic compounds № 1 and 2, respectively, compared with similar parameters of control barley plants treated with distilled water (Fig. 3).

Auxins IAA, NAA and synthetic compounds № 3 and 7 showed lower growth-regulating activity; the average length of the roots (mm) of barley plants increased as follows: by 15.45 – 32.81 % - after treatment with IAA and NAA, and by 17.97 – 29.46 % - after treatment with synthetic compounds № 3 and 7, respectively, compared with similar parameters of control barley plants treated with distilled water (Fig. 3).

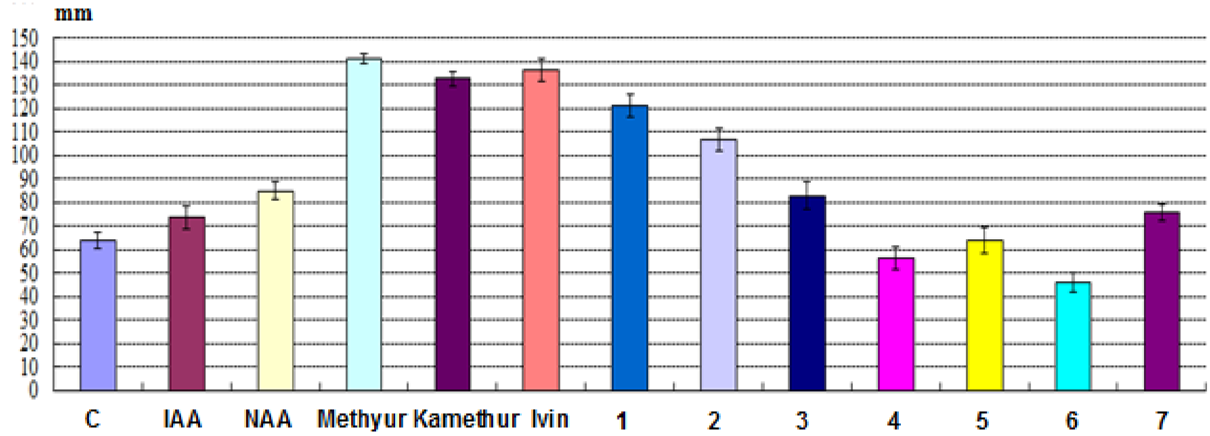


Figure 3. The regulatory effect of auxins IAA and NAA, synthetic compounds, derivatives of pyrimidine (Methyur, Kamethur and compounds № 1 – 7) and pyridine (Ivin) at a concentration of 10^{-7}M on an average length of the roots (mm) of 2-week-old spring barley (Hordeum vulgare L.) variety Avatar, compared to control plants (C)

The highest parameters of the average biomass (g) of 10 barley plants, which exceeded similar parameters of control plants by 30.59 – 86.46 %, were obtained on 2-week-old barley plants treated with synthetic compounds, derivatives of N-oxide-2,6-dimethylpyridine (Ivin), sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur and Kamethur), compound № 2 - 6-methyl-2-propylsulfanyl-pyrimidin-4-ol, and compound № 5 - sodium 4-hydroxypyrimidine--2-thiolate, respectively (Fig. 4).

The parameters of the average biomass (g) of 10 barley plants increased as follows: by 30.59 % - after treatment with Ivin, by 86.46 % - after treatment with Methyur, by 46.28 % - after treatment with Kamethur, by 60.25 – 71.94 % - after treatment with synthetic compounds № 2 and 5, respectively, compared with similar parameters of control barley plants treated with distilled water (Fig. 4).

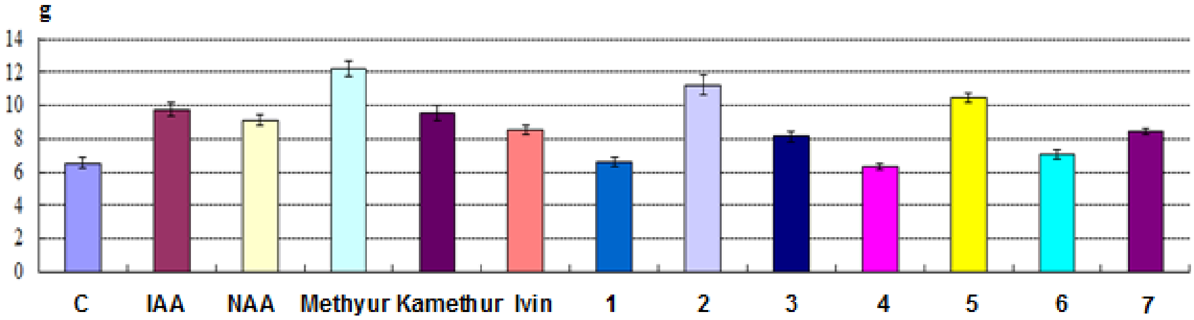


Figure 4. The regulatory effect of auxins IAA and NAA, synthetic compounds, derivatives of pyrimidine (Methyur, Kamethur and compounds № 1 – 7) and pyridine (Ivin) at a concentration of 10^{-7}M on an average biomass (g) of 2-week-old spring barley (Hordeum vulgare L.) variety Avatar, compared to control plants (C)

Auxins IAA, NAA showed similar growth-regulating activity; the average biomass (g) of 10 barley plants increased by 39.59 – 49.01 % - after treatment with IAA and NAA, respectively, compared with similar parameters of control barley plants treated with distilled water (Fig. 4).

Synthetic compounds № 3, 6 and 7 showed lower growth-regulating activity; the average biomass (g) of 10 barley plants increased by 7.92 – 29.45 % - after treatment with synthetic compounds № 3, 6 and 7, respectively, compared with similar parameters of control barley plants treated with distilled water (Fig. 4).

Summarizing the obtained data on the morphometric parameters of 2-week-old spring barley (*Hordeum vulgare* L.) variety Avatar, it should be noted that the highest growth-regulating activity was found in synthetic compounds, derivatives of pyrimidine and pyridine: Methyur, Kamethur, Ivin, as well as the compounds № 1, 2, 3 and 5. The activity of these synthetic compounds applied at a concentration of 10^{-7}M was similar to or exceeded the activity of auxins IAA and NAA, applied at a similar concentration.

It should be noted that after treatment of barley plants with auxins IAA and NAA at a concentration of 10^{-7}M, the average length of the roots (mm) of barley plants increased to a lesser extent than after treatment with synthetic pyridine and pyrimidine derivatives, compared to control plants. The obtained data indicate that synthetic compounds, derivatives of pyrimidine and pyridine show a stimulating effect on the growth of the main roots of plants, which is less characteristic of auxins, which are known to inhibit the elongation of main roots in some plant species, slowing down their growth in length [40, 41]. Therefore, in our studies, a weak stimulating effect of auxins IAA and NAA on the growth of the main roots of barley plants was also observed, which is apparently explained by their application in a rather low concentration of 10^{-7}M, which does not cause inhibition of root growth in length.

Analyzing the relationship between the chemical structure and biological activity of new synthetic compounds, derivatives of pyrimidine, compounds № 1, 2, 3 and 5, it can be assumed that the high auxin-like activity of these compounds is associated with the presence of substituents in their chemical structure: compound № 1 contains an ethylthio group in position 2, a hydroxyl group in position 4 and a methyl group in position 6; compound № 2 contains a propylthio group in position 2, a hydroxyl group in position 4 and a methyl group in position 6; compound № 3 contains a benzylthio group in position 2, a hydroxyl group in position 4 and a methyl group in position 6; compound № 5 is the sodium salt of 4-hydroxypyrimidine-2-thiolate (Table 1).

At the same time, the decrease in auxin-like activity in synthetic compounds, pyrimidine derivatives № 4, 6, and 7 can be explained by the presence of substituents in the chemical structures of these compounds: compound № 4 contains an isopropyl substituent in position 2, a hydroxyl group in position 4, and a methyl group in position 6; compound № 6 contains a methylthio group in position 2 and a hydroxyl group in position 4; compound № 7 contains a benzylthio group in position 2 and a hydroxyl group in position 4 (Table 1).

It is possible to assume that the high growth-regulating activity of most active synthetic compounds, derivatives of pyrimidine and pyridine: Methyur, Kamethur, Ivin, as well as the compounds № 1, 2, 3 and 5, is explained by their specific auxin-like stimulating effect on the proliferation, elongation and differentiation of plant cells, which are the main processes of the formation and development of plant shoots and roots, as well on the biosynthesis, metabolism and signaling of endogenous auxins in plant cells [9, 10, 29, 34, 35, 40 - 45].

Study of the effect of synthetic compounds, pyrimidine and pyridine derivatives on the content of photosynthetic pigments in plant leaves.

As is known, phytohormones cytokinins play an important role in the regulation of chloroplast differentiation and the biosynthesis of photosynthetic pigments, which are the main indicators of plant productivity [46, 47].

The cytokinin-like effect of synthetic compounds, pyrimidine and pyridine derivatives at a concentration of 10^{-7}M on the content of photosynthetic pigments: chlorophyll a, chlorophyll b, chlorophyll a+b, and carotenoids in the leaves of 2-week-old spring barley (*Hordeum vulgare* L.) variety Avatar was studied.

Our studies have shown that pyrimidine and pyridine derivatives at a concentration of 10^{-7}M exhibit cytokinin-like activity in increasing the content of photosynthetic pigments in the leaves of barley plants. The content of chlorophyll a increased as follows: by 6.46% - under the influence of Ivin, by 68.33% - under the influence of Methyur, by 40.74% - under the influence of Kamethur, by 15,84 - 48.94% - under the influence of synthetic compounds № 1-7, respectively, compared with similar parameters of control barley plants treated with distilled water (Fig. 5). The content of chlorophyll b increased as follows: by 6.2% - under the influence of Ivin, by 62.94% - under the influence of Methyur, by 35.66% - under the influence of Kamethur, by 10.89 - 64.11% - under the influence of synthetic compounds № 1-7, respectively, compared with similar parameters of control barley plants treated with distilled water (Fig. 5). The content of chlorophyll a+b increased as follows: by 6.37% - under the influence of Ivin, by 66.81% - under the influence of Methyur, by 39.31% - under the influence of Kamethur, by 3.1 - 66.79% - under the influence of synthetic compounds № 1-7, respectively, compared with similar parameters of control barley plants treated with distilled water (Fig. 5). The content of carotenoids increased as follows: by 29.81% - under the influence of Methyur, by 19.24% - under the influence of Kamethur, by 2.65 - 21.19% - under the influence of synthetic compounds № 1, 2, 3, 6 and 7, respectively, compared with similar parameters of control barley plants treated with distilled water (Fig. 5).

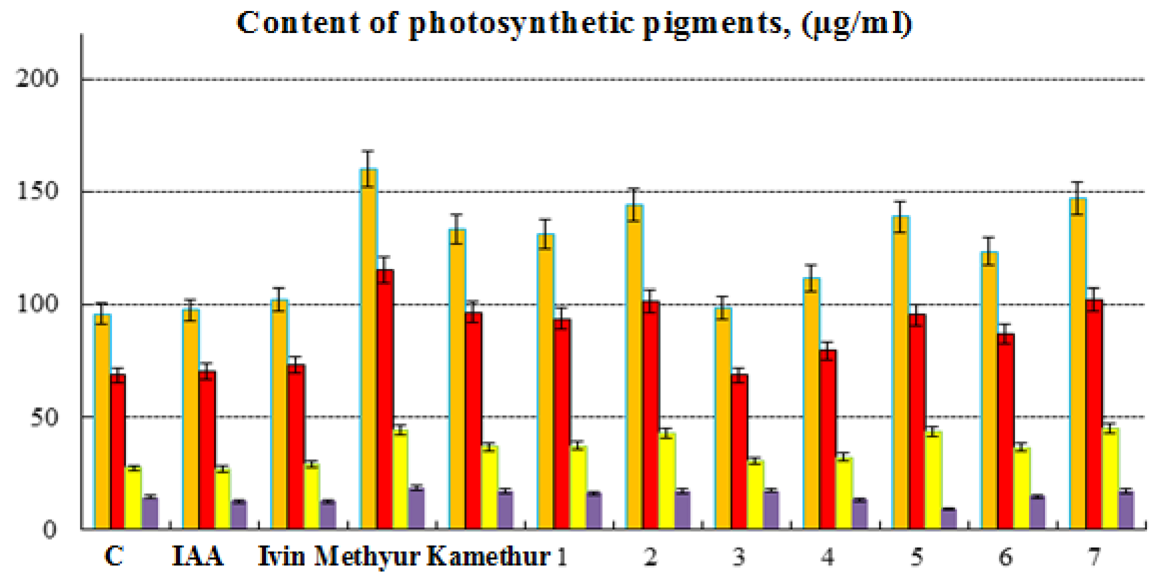


Figure 5. The effect of auxin IAA, synthetic compounds, derivatives of pyrimidine (Methyur, Kamethur and compounds № 1 – 7) and pyridine (Ivin) at a concentration of 10^{-7}M on the content of photosynthetic pigments: chlorophyll a, chlorophyll b, chlorophyll a+b, carotenoids (µg/ml) in the leaves of 2-week-old spring barley (Hordeum vulgare L.) variety Avatar, compared with control plants (C)

The comparative studies have shown a lower activity of auxin IAA at a concentration of 10^{-7}M in increasing the content of photosynthetic pigments in the leaves of barley plants. The content of chlorophyll a increased by 2.82% and the content of chlorophyll a+b increased by 1.8%, respectively, under the influence of IAA compared with similar parameters of control barley plants treated with distilled water (Fig. 5).

Thus, the obtained results confirmed the positive effect of synthetic compounds, pyrimidine and pyridine derivatives: Methyur, Kamethur, Ivin and the most active compounds № 1, 2, 5, 6 and 7 at a concentration of 10^{-7}M on increasing the content of chlorophylls and carotenoids in the leaves of 2-week-old spring barley (*Hordeum vulgare* L.) variety Avatar, which play a key role in photosynthesis and ensuring plant productivity.

Conclusion.

Study of the growth-regulating activity of synthetic compounds, pyrimidine and pyridine derivatives showed that their use for processing barley seeds at a concentration of 10^{-7}M contributes to the improvement of the growth and development of roots and shoots of spring barley (*Hordeum vulgare* L.) variety Avatar for 2 weeks and increases the content of photosynthetic pigments in plant leaves. The plant growth-regulating activity of these synthetic compounds was similar or exceeded that of auxins IAA and NAA used at similar concentration of 10^{-7}M. The practical use of the synthetic compounds, pyrimidine and pyridine derivatives: Methyur, Kamethur, Ivin, as well as the most active selected compounds № 1, 2, 3, 5 and 7 for improving the development of shoots and roots, increasing the biomass of spring barley (*Hordeum vulgare* L.) variety Avatar in the vegetative phase, and increasing the content of photosynthetic pigments in plant leaves is proposed.

Statement of Conflict of Interest.

The authors are declared that they have no conflict with this research article.

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