

## New Wheat Growth Regulators Based On Thioxopyrimidine Derivatives

Research Article

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## Abstract

Screening of new growth regulators of wheat (*Triticum aestivum* L.) variety Demira among synthetic low molecular weight heterocyclic compounds, thioxopyrimidine derivatives, was carried out. The plant growth-regulating activity of synthetic low molecular weight heterocyclic compounds, thioxopyrimidine derivatives was compared with the activity of plant hormone auxin IAA - (1*H*-indol-3-yl)acetic acid), or with the activity of known synthetic low molecular weight heterocyclic compounds, derivatives of sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur, Kamethur) and N-oxide-2,6-dimethylpyridine (Ivin). For this purpose, wheat seeds were soaked for 48 hours with water solutions of all the studied compounds at a concentration of 10<sup>-6</sup>M. Control wheat plants were soaked with distilled water. Morphometric parameters (average length of shoots (mm), average length of roots (mm), and average biomass of 10 plants (g)), biochemical parameters (content of photosynthetic pigments chlorophylls a, b, a+band carotenoids (μg/ml)) of wheat plants were measured after 2 weeks. It has been shown that some synthetic low molecular weight heterocyclic compounds, thioxopyrimidine derivatives exhibit high growth regulating activity on the morphometric and biochemical parameters of wheat plants, similar or higher than the activity of IAA, Methyur, Kamethur and Ivin. The activity of synthetic low molecular weight heterocyclic compounds, thioxopyrimidine derivatives is differentiated depending on their chemical structure. The most active synthetic low molecular weight heterocyclic compounds, thioxopyrimidine derivatives, were selected and proposed to be used as new growth regulators of wheat (*Triticum aestivum* L.) variety Demira.

**Keywords:** Wheat; Auxin IAA, Plant Growth Regulators; Methyur; Kamethur; Ivin; Thioxopyrimidine Derivatives.

## Introduction

One of the most important tasks of modern agrobiotechnology is the development of new environmentally friendly plant growth regulators to increase yields and improve the quality of crop products, as well as increase plant resistance to stress factors of abiotic and biotic origin [1, 2]. Special attention is focused on plant biostimulants, which contain compounds of synthetic and natural origin, non-toxic for animals, humans and the environment, increase the immune properties of plants to pathogenic fungi, parasitic nematodes, insects and abiotic stresses [3-5].

A new promising approach is the development of new environmentally friendly plant growth regulators based on synthetic low molecular weight heterocyclic compounds, pyrimidine and pyridine derivatives, which are used as therapeutic agents in medicine [6-12], as well as pesticides and fungicides in agriculture [13-22]. Among the currently known plant growth regulators created on the basis of synthetic low molecular weight heterocyclic compounds are derivatives of sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur, Kamethur) and N-oxide-2,6-dimethylpyridine (Ivin) [23-28]. These plant growth regulators have regulatory effects, similar to plant hormones, on

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the growth and development of important grains, legumes, vegetables, industrial and horticultural crops, increasing their productivity and resistance to abiotic stress factors [23-28]. The use of these plant growth regulators allows reducing the use of pesticides and fungicides that are toxic to humans and animals [29, 30], which has a significant economic effect for agriculture and contributes to the solution of ecological problems for the environment.

In recent years, among synthetic lowmolecular weight heterocyclic compounds, new biologically active compounds have been discovered that can increase plant productivity by improving the growth and development of plant roots, shoots, and leaves, and enhancing the processes of photosynthesis and protein biosynthesis [31-36]. Along with this, the screening for new synthetic low molecular weight heterocyclic compounds, pyrimidine derivatives, which reveal a regulatory effect related to auxins and cytokinins or synthetic plant growth regulators Methyur, Kamethur or Ivin, is carried out [37-43].

As is known, plant photosynthetic pigments play a key role in photosynthesis and photoprotection of plants and ensure their productivity [44-46]; in addition, plant pigments such as  $\alpha$ -carotene,  $\beta$ -carotene,  $\beta$ -cryptoxanthin, lutein, zeaxanthin, lycopene are important biologically active compounds that have found practical use in medicine as therapeutic agents for the prevention and treatment of various human diseases [47, 48]. Our recent studies on various agricultural crops show that the regulatory activity of

new synthetic low molecular weight heterocyclic compounds, pyrimidine derivatives on plant growth and development, as well as on the synthesis of photosynthetic pigments chlorophylls and carotenoids in plant leaves, is similar or higher than the activity of plant hormones auxins and cytokinins or synthetic plant growth regulators Methyur, Kamethur and Ivin [37-43].

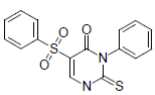
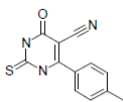
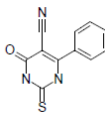
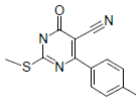
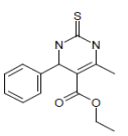
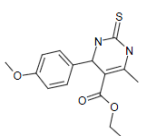
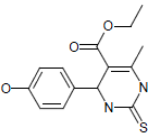
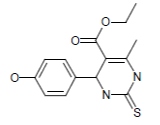
The purpose of this work is the screening of new biologically active compounds among synthetic low molecular weight heterocyclic compounds, thioxopyrimidine derivatives, capable of exerting a regulatory effect on growth and photosynthesis of an important grain crop - wheat (*Triticum aestivum* L.) variety Demira.

## Materials And Methods

**Chemical structures of the studied compounds:** The known synthetic low molecular weight heterocyclic compounds, derivatives of sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur, Kamethur), N-oxide-2,6-dimethylpyridine (Ivin) and new synthetic low molecular weight heterocyclic compounds, derivatives of thioxopyrimidine derivatives (compounds № 1–11) were synthesized using methods [49-54] at 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 (Table 1). Plant hormone auxin IAA (1H-indol-3-yl)acetic acid) was manufactured by Sigma-Aldrich, USA (Table 1).

**Table 1. Chemical structures of plant hormone auxin IAA - (1H-indol-3-yl)acetic acid), synthetic low molecular weight heterocyclic compounds, derivatives of sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur, Kamethur), N-oxide-2,6-dimethylpyridine (Ivin) and thioxopyrimidine derivatives (compounds № 1–11).**

Chemical compound	Chemical structure	Chemical name and relative molecular weight (g/mol)
IAA		1H-indol-3-ylacetic acid MW=175.19
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		5-Benzenesulfonyl-3-ethyl-2-thioxo-2,3-dihydro-1H-pyrimidin-4-one MW=296.3690
2		3-Allyl-5-benzenesulfonyl-2-thioxo-2,3-dihydro-1H-pyrimidin-4-one MW=308.3802
3		5-Benzyl-6-methyl-2-thioxo-2,3-dihydro-1H-pyrimidin-4-one MW=232.3062

4		5-Benzenesulfonyl-3-phenyl-2-thioxo-2,3-dihydro-1H-pyrimidin-4-one MW=344.4136
5		4-Oxo-2-thioxo-6-p-tolyl-1,2,3,4-tetrahydropyrimidine-5-carbonitrile MW=243.2890
6		4-Oxo-6-phenyl-2-thioxo-1,2,3,4-tetrahydropyrimidine-5-carbonitrile MW=229.2619
7		2-Methylsulfanyl-6-oxo-4-p-tolyl-1,6-dihydropyrimidine-5-carbonitrile MW=257.3161
8		6-Methyl-4-phenyl-2-thioxo-1,2,3,4-tetrahydropyrimidine-5-carboxylic acid ethyl ester MW=276
9		4-(4-Methoxy-phenyl)-6-methyl-2-thioxo-1,2,3,4-tetrahydro-pyrimidine-5-carboxylic acid ethylester MW=306
10		4-(4-Methoxycarbonyl-phenyl)-6-methyl-2-thioxo-1,2,3,4-tetrahydro-pyrimidine-5-carboxylic acid ethylester MW=334
11		4-(4-Hydroxy-phenyl)-6-methyl-2-thioxo-1,2,3,4-tetrahydro-pyrimidine-5-carboxylic acid ethylester MW=292

### Plant treatment and growing conditions

The seeds of wheat (*Triticum aestivum* L.) variety Demir were sterilized with 1 %  $\text{KMnO}_4$  solution for 15 min, then treated with 96 % ethanol solution for 1 min, after which they were washed three times with sterile distilled water. After this procedure, wheat seeds were placed in the plastic cuvettes (each containing 15 - 20 seeds) on the perlite moistened with distilled water (control sample), or water solutions of plant hormone auxin IAA - (1H-indol-3-yl) acetic acid), or studied synthetic low molecular weight heterocyclic compounds, derivatives of sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur, Kamethur), N-oxide-2,6-dimethylpyridine (Ivin) and thioxopyrimidine derivatives (compounds № 1–11), which were used at a concentration of  $10^{-6}\text{M}$  (experimental samples). Then the wheat seeds were placed in a thermostat for germination in the dark at a temperature of 20–22°C. After 48 hours, wheat seedlings were placed in a climate chamber, where they were grown at the 16/8 h light/dark conditions, at the temperature 20–22°C, light intensity of 3000 lux, and air humidity 60–80%.

### Determination of morphometric and biochemical parameters of wheat plants.

Morphometric parameters of wheat plants (average length of shoots (mm), average length of roots (mm), and average biomass of 10 plants (g)) were measured after 2 weeks according to methodological recommendations [55]. The morphometric parameters determined in the wheat plants of the experimental samples compared to the similar parameters determined in the wheat plants of the control samples were expressed as (%).

Biochemical parameters of wheat plants (content of photosynthetic pigments ( $\mu\text{g/ml}$ )) were also measured after 2 weeks according to methodological recommendations [44–46]. To perform the extraction of photosynthetic pigments, we homogenized a sample (500 mg) of wheat 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  $\text{CaCO}_3$  (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 SpecordM-40 (Carl Zeiss, Germany).

The content of chlorophyll a, chlorophyll b, and carotenoids in wheat leaves was calculated in accordance with formula:

$$\begin{aligned} \text{Cchl a} &= 13.36 \times A_{664.2} - 5.19 \times A_{648.6}, \\ \text{Cchl b} &= 27.43 \times A_{648.6} - 8.12A \times 664.2, \\ \text{Cchl (a + b)} &= 5.24 \times A_{664.2} + 22.24 \times A_{648.6}, \\ \text{Ccar} &= (1000 \times A_{470} - 2.13 \times \text{Cchl a} - 97.64 \times \text{Cchl b}) / 209, \end{aligned}$$

Where,

Cchl – concentration of chlorophylls ( $\mu\text{g/ml}$ ), Cchl a – concentration of chlorophyll a ( $\mu\text{g/ml}$ ), Cchl b – concentration of chlorophyll b ( $\mu\text{g/ml}$ ), Ccar – concentration of carotenoids ( $\mu\text{g/ml}$ ), A – absorbance value at a proper wavelength in nm.

The chlorophyll and carotenoids content per 1 g of fresh weight (FW) of extracted from wheat 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, A1 – content of chlorophyll a, chlorophyll b, or carotenoids (mg/g FW),

C - concentration of pigments ( $\mu\text{g/ml}$ ),

V - volume of extract (ml),

$a_1$  - sample of wheat leaves (g).

The biochemical parameters determined in the wheat plants of the experimental samples compared to the similar parameters determined in the wheat plants of the control samples were expressed as (%).

### Statistical data analysis

Each experiment was performed three times. Statistical processing of the experimental data was carried out using Student's t-test with a significance level of  $P \leq 0.05$ ; mean values  $\pm$  standard deviation ( $\pm$  SD) [56].

## Results and Discussion

**Study of morphometric parameters of wheat plants.** The plant growth-regulating activity of synthetic low molecular weight heterocyclic compounds, thioxopyrimidine derivatives was studied. It was shown that synthetic low molecular weight heterocyclic compounds, thioxopyrimidine derivatives exhibit similar or higher activity to the plant hormone auxin IAA - (1H-indol-3-yl)acetic acid) orderivatives of sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur, Kamethur) and N-oxide-2,6-dimethylpyridine (Ivin).

Wheat plants obtained from seeds treated with water solutions of all studied synthetic compounds at a concentration of  $10^{-6}$  M grew more intensively and had more developed roots and shoots compared to control wheat plants treated with distilled water (Fig.

1).

Morphometric parameters (average length of shoots (mm)) of the experimental wheat plants, measured after 2 weeks, exceeded the morphometric parameters of the control wheat plants.

The synthetic low molecular weight heterocyclic compounds Ivin, Methyur, Kamethur and thioxopyrimidine derivatives № 1, 4–8 showed the highest activity; the parameters of the average length of shoots increased: by 64,95% - after treatment with Ivin, by 63,92% - after treatment with Methyur, by 57,73 % - after treatment with Kamethur, by 45,36–70,61% - after treatment with most active thioxopyrimidine derivatives № 1, 4–8, respectively, compared to control plants (Fig. 2).

Auxin IAA and synthetic low molecular weight heterocyclic compounds, thioxopyrimidine derivatives № 2, 3, 9–11 showed lower activity; the parameters of the average length of shoots increased: by 32,99% - after treatment with auxin IAA, by 10,31–44,33% - after treatment with thioxopyrimidine derivatives № 2, 3, 9–11, respectively, compared to control plants (Fig. 2).

Morphometric parameters (average length of roots (mm)) of the experimental wheat plants, measured after 2 weeks, exceeded the morphometric parameters of the control wheat plants.

Auxin IAA and synthetic low molecular weight heterocyclic compounds Ivin, Methyur, Kamethur and thioxopyrimidine derivatives № 1, 4–8, 11 showed the highest activity; the parameters of the average length of roots increased: by 87,93% - after treatment with auxin IAA, by 86,21 % - after treatment with Ivin, by 84,62 % - after treatment with Methyur, by 75,86 % - after treatment with Kamethur, by 74,13–150 % - after treatment with most active thioxopyrimidine derivatives № 1, 4–8, 11, respectively, compared to control plants (Fig. 3).

Synthetic low molecular weight heterocyclic compounds, thioxopyrimidine derivatives № 2, 3, 9, 10, showed lower activity; the parameters of the average length of roots increased: by 24,14–68,97% - after treatment with thioxopyrimidine derivatives № 2, 3, 9, 10, respectively, compared to control plants (Fig. 3).

Morphometric parameters (average biomass of 10 plants (g)) of the experimental wheat plants, measured after 2 weeks, exceeded the morphometric parameters of the control wheat plants.

The synthetic low molecular weight heterocyclic compounds Ivin, Methyur, Kamethur and thioxopyrimidine derivatives № 1–9, 11 showed the highest activity; the parameters of the average biomass of 10 plants increased: by 86,67 % - after treatment with Ivin, by 58,33 % - after treatment with Methyur, by 67,5 % - after treatment with Kamethur, by 64,17–125,83 % - after treatment with most active thioxopyrimidine derivatives № 1–9, 11, respectively, compared to control plants (Fig. 4).

Auxin IAA and synthetic heterocyclic compound, thioxopyrimidine derivative № 10 showed lower activity; the parameters of the average biomass of 10 plants increased: by 34,17 % - after treatment with auxin IAA, by 51,67 % - after treatment with thioxopyrimidine derivative № 10, respectively, compared to control plants (Fig. 4).



Figure 1. The effect of auxin IAA and synthetic low molecular weight heterocyclic compounds Methyur, Kamethur, Ivin and thioxopyrimidine derivatives № 1 – 11 at a concentration of  $10^{-6}$ M on the growth of shoots and roots of 2-week-old wheat (*Triticumaestivum* L.) variety Demira compared to control plants.

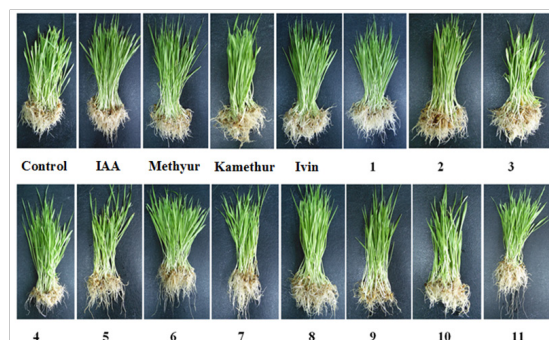


Figure 2. The effect of auxin IAA and synthetic low molecular weight heterocyclic compounds Ivin, Methyur, Kamethur and thioxopyrimidine derivatives № 1 – 11 at a concentration of  $10^{-6}$ M on the average length of shoots (mm) of 2-week-old wheat (*Triticumaestivum* L.) variety Demira compared to control plants.

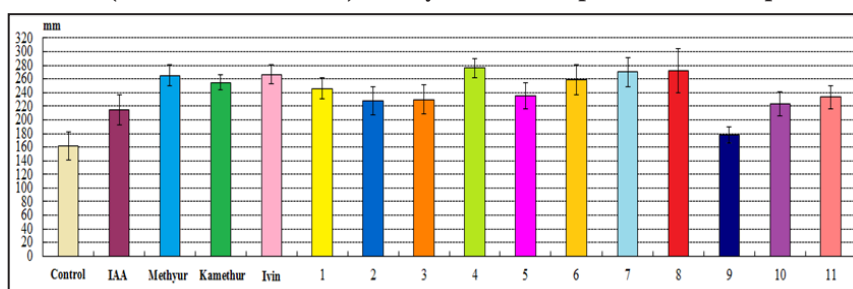


Figure 3. The effect of auxin IAA and synthetic low molecular weight heterocyclic compounds Ivin, Methyur, Kamethur and thioxopyrimidine derivatives № 1 – 11 at a concentration of  $10^{-6}$ M on the average length of roots (mm) of 2-week-old wheat (*Triticumaestivum* L.) variety Demira compared to control plants.

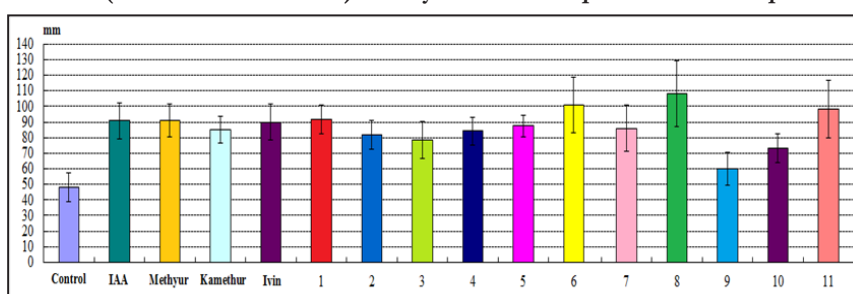
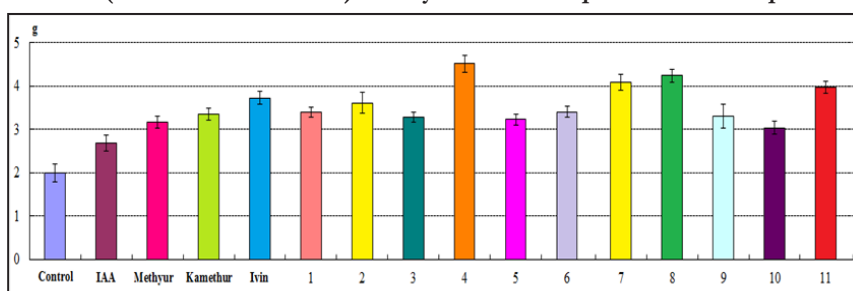


Figure 4. The effect of auxin IAA and synthetic low molecular weight heterocyclic compounds Ivin, Methyur, Kamethur and thioxopyrimidine derivatives № 1 – 11 at a concentration of  $10^{-6}$ M on the average biomass of 10 plants (g) of 2-week-old wheat (*Triticumaestivum* L.) variety Demira compared to control plants.



Summarizing the obtained data, it should be noted that synthetic low molecular weight heterocyclic compounds, derivatives of N-oxide-2,6-dimethylpyridine (Ivin), sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur, Kamethur), and thioxopyrimidine derivatives № 1, 4–8, 11 showed the highest plant growth-regulating activity. The activity of these synthetic low molecular weight heterocyclic compounds, applied at a concentration of  $10^{-6}$ M, was similar to or exceeded the activity of auxin IAA, applied at a similar concentration. It is obvious that

the growth-regulating activity of synthetic low molecular weight heterocyclic compounds, similar to auxin IAA, is explained by their auxin-like and cytokinin-like effects on plant cell proliferation, elongation, and differentiation, which are the main processes of the formation and development of shoots and roots [57-59].

**Study of biochemical parameters of wheat plants.** The effect of synthetic low molecular weight heterocyclic compound on the content of photosynthetic pigments in the leaves of wheat plant-

swas also studied. It was found that the biochemical parameters (content of chlorophyll a, chlorophyll b, chlorophylls a+b, and carotenoids ( $\mu\text{g/ml}$ )) in the leaves of the experimental wheat plants, measured after 2 weeks, exceeded the biochemical parameters of the control wheat plants.

The synthetic low molecular weight heterocyclic compounds Methyur, Kamethur and thioxopyrimidine derivatives № 1, 2, 4, 5, 6, 7, 10 and 11 showed the highest activity. The biochemical parameters (content of chlorophyll a, chlorophyll b, chlorophylls a+b, and carotenoids ( $\mu\text{g/ml}$ )) increased: chlorophyll a - by 82 % - after treatment with Methyur, by 95,15 % - after treatment with Kamethur, by 44,72–88,83 % - after treatment with thioxopyrimidine derivatives № 1, 2, 4, 5, 6, 7, 10 and 11; chlorophyll b - by 74,98 % - after treatment with Methyur, by 88,56 % - after treatment with Kamethur, by 53,66–101,36 % - after treatment with thioxopyrimidine derivatives № 1, 2, 4, 5, 6, 7, 10 and 11; chlorophylls a+b - by 79,65 % - after treatment with Methyur, by 92,97 % - after treatment with Kamethur, by 47,897–93,02 % - after treatment with thioxopyrimidine derivatives № 1, 2, 4, 5, 6, 7, 10 and 11; carotenoids - by 62,35 % - after treatment with Methyur, by 71,55 % - after treatment with Kamethur, by 24,86–66,68 % - after treatment with thioxopyrimidine derivatives № 1, 2, 4, 5, 6, 7, 10 and 11, respectively, compared to control plants (Fig. 5).

Auxin IAA, synthetic low molecular weight heterocyclic compounds Ivin and thioxopyrimidine derivatives № 3 and 9 showed lower activity. The biochemical parameters (content of chlorophyll a, chlorophyll b, chlorophylls a+b, and carotenoids ( $\mu\text{g/ml}$ )) increased: chlorophyll a - by 53,18 % - after treatment with auxin IAA, by 47,15 % - after treatment with Ivin, by 2,96–25,32 % - after treatment with thioxopyrimidine derivatives № 3 and 9; chlorophyll b - by 50,06 % - after treatment with auxin IAA, by 33,1 % - after treatment with Ivin, by 15,42–39,55 % - after treatment with thioxopyrimidine derivatives № 3 and 9; chlorophylls a+b - by 52,13 % - after treatment with auxin IAA, by 42,45 % - after treatment with Ivin, by 17,18–30,08 % - after treatment with thioxopyrimidine derivatives № 3 and 9; carotenoids - by 43,27 % - after treatment with auxin IAA, by 55,58 % - after treatment with Ivin, by 68,57–69,343 % - after treatment with thioxopyrimidine derivatives № 3 and 9, respectively, compared to control plants (Fig. 5).

The synthetic heterocyclic compound, thioxopyrimidine derivative № 8 showed a stimulating activity only on the content of carotenoids ( $\mu\text{g/ml}$ ) in the leaves of wheat plants, which increased

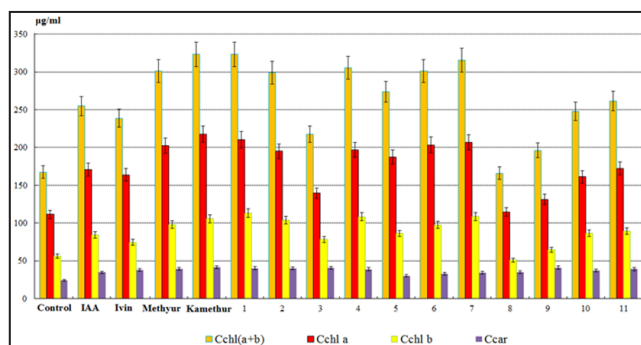
by 43,69 % compared to control plants, while the content of chlorophylls a, b, a+b ( $\mu\text{g/ml}$ ) were not statistically significantly different from the control plants (Fig. 5).

Thus, the obtained results confirmed that synthetic low molecular weight heterocyclic compounds, derivatives of sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur, Kamethur) and thioxopyrimidine derivatives № 1, 2, 4, 5, 6, 7, 10 and 11 revealed the highest stimulating activity on the content of photosynthetic pigments (chlorophyll a, chlorophyll b, chlorophylls a+b, and carotenoids ( $\mu\text{g/ml}$ )) in the leaves of wheat plants. The activity of these synthetic low molecular weight heterocyclic compounds, applied at a concentration of  $10^{-6}\text{M}$ , was similar to or exceeded the activity of auxin IAA, applied at a similar concentration.

This fact can be explained by the assumption that the increase in the content of photosynthetic pigments in the leaves of wheat plants is associated with the cytokinin-like effect of synthetic low molecular weight heterocyclic compounds, thioxopyrimidine derivatives on increasing the synthesis and slowing down the degradation of chlorophyll a, b and carotenoids in plant cells, which play a key role in photosynthesis and plant productivity [44-46, 59-62].

Summarizing the obtained morphometric and biochemical parameters of wheat plants and analyzing the relationship between the chemical structure and biological activity of most active synthetic low molecular weight heterocyclic compounds, thioxopyrimidine derivatives № 1, 4, 5, 6, 7 and 11, it can be assumed that their high plant growth-regulating activity and effect on the process of photosynthesis in plant leaves is associated with the presence of substituents in their chemical structure (Table 1): compound № 1 contains a benzenesulfonyl group in position 5, an ethyl group in position 3 of the 2-thioxo-2,3-dihydro-1H-pyrimidin-4-one ring; compound № 4 contains a phenyl group in position 3, a benzenesulfonyl group in position 5 of the 2-thioxo-2,3-dihydro-1H-pyrimidin-4-one ring; compound № 5 contains a p-tolyl group in position 6, a cyano group in position 5 of the 4-oxo-2-thioxo-1,2,3,4-tetrahydropyrimidine ring; compound № 6 contains a phenyl group in position 6, a cyano group in position 5 of the 4-oxo-2-thioxo-1,2,3,4-tetrahydropyrimidine ring; compound № 7 contains a methylsulfonyl group in position 2, a p-tolyl group in position 4, and a cyano group in position 5 of the 6-oxo-1,6-dihydropyrimidine ring; compound № 11 contains a methyl group in position 6, a 4-hydroxyphenyl group in position

**Figure 5. The effect of auxin IAA and synthetic low molecular weight heterocyclic compounds Ivin, Methyur, Kamethur and thioxopyrimidine derivatives № 1 – 11 at a concentration of  $10^{-6}\text{M}$  on the content of chlorophylls a, b, a+b and carotenoids ( $\mu\text{g/ml}$ ) in the leaves of 2-week-old wheat (*Triticum aestivum* L.) variety Demira compared to control plants.**



4, and an ethoxycarbonyl group in position 5 of the 2-thioxo-1,2,3,4-tetrahydropyrimidine ring.

The decrease in the plant growth-regulating activity of synthetic low molecular weight heterocyclic compounds, thioxopyrimidine derivatives № 2, 3, 8, 9 and 10 and their effect on the process of photosynthesis in plant leaves can be explained by the presence of substituents in the chemical structures of these compounds (Table 1): compound № 2 contains an allyl substituent in position 3, a phenylsulfonyl group in position 5 of the 2-thioxo-2,3-dihydro-1H-pyrimidin-4-one ring; compound № 3 contains a benzyl substituent in position 5, a methyl group in position 6 of the 2-thioxo-2,3-dihydro-1H-pyrimidin-4-one ring; compound № 8 contains a methyl group in position 6, a phenyl group in position 4, and an ethoxycarbonyl group in position 5 of the 2-thioxo-1,2,3,4-tetrahydropyrimidine ring; compound № 9 contains a methyl group in position 6, a 4-methoxyphenyl group in position 4, and an ethoxycarbonyl group in position 5 of the 2-thioxo-1,2,3,4-tetrahydropyrimidine ring; compound № 10 contains a methyl group in position 6, a 4-methoxycarbonylphenyl group in position 4, and an ethoxycarbonyl group in position 5 of the 2-thioxo-1,2,3,4-tetrahydropyrimidine ring.

Based on the obtained results, it can be assumed that the plant growth-regulatory activity of synthetic low molecular weight heterocyclic compounds, thioxopyrimidine derivatives, occurs due to increasing or decreasing the activity of key enzymes of biosynthesis, metabolism and transport of endogenous auxins and cytokinins in plant cells, as well as due to their participation in auxin and cytokinin signaling pathways [63-72].

## Conclusion

The growth-regulating effect of synthetic low molecular weight heterocyclic compounds, thioxopyrimidine derivatives on the morphometric and biochemical parameters of wheat plants was studied. The activity of the synthetic low molecular weight heterocyclic compounds, thioxopyrimidine derivatives applied at a concentration of 10<sup>-6</sup>M, was similar or exceeded the activity of auxin IAA, applied at a similar concentration. The obtained morphometric parameters (average length of shoots (mm), average length of roots (mm), and average biomass of 10 plants (g)) and biochemical parameters (content of photosynthetic pigments chlorophylls a, b, a+b and carotenoids (µg/ml)) of experimental wheat plants treated with synthetic low molecular weight heterocyclic compounds, thioxopyrimidine derivatives, exceeded the biochemical parameters of the control wheat plants. It was concluded that the biological activity of synthetic low molecular weight heterocyclic compounds, thioxopyrimidine derivatives, depends on their chemical structure. The selected most biologically active synthetic low molecular weight heterocyclic compounds, thioxopyrimidine derivatives № 1, 4, 5, 6, 7 and 11 are proposed to be used as new growth regulators of wheat (*Triticum aestivum* L.) variety Demira.

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