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Research Article

Application of Pyrimidine Derivatives as New Regulators to Enhance Wheat Growth in The Vegetative Phase

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Abstract:

The regulatory effect of synthetic low-molecular-weight azaheterocyclic compounds, pyrimidine derivatives on the growth and photosynthesis of winter wheat (*Triticum aestivum* L.) variety Taira in the vegetative phase was studied. Wheat growth parameters such as average shoot length (mm) and average root length (mm) and wheat photosynthesis parameters such as chlorophyll and carotenoid content (mg/g fresh weight) under the regulatory effect of pyrimidine derivatives were measured 4 weeks after seed germination and compared with those of control wheat grown in distilled water or wheat grown under the regulatory effect of auxin IAA. The study showed that the wheat growth parameters and photosynthetic parameters under the regulatory effect of synthetic compounds, pyrimidine derivatives at a concentration of 10^{-6}M were similar to or higher than the parameters of wheat under the regulatory effect of auxin IAA at a similar concentration of 10^{-6}M, and also exceeded that of the control wheat grown in distilled water. The selectivity of the regulatory effect of synthetic compounds, pyrimidine derivatives on wheat growth and photosynthesis depended on the substituents in their chemical structure. The most physiologically active synthetic compounds, pyrimidine derivatives have been proposed for use to enhance the growth and photosynthesis of wheat in the vegetative phase.

Key words: Wheat; azaheterocyclic compounds; pyrimidine derivatives; IAA

Introduction

Wheat (*Triticum aestivum* L.) is a major cereal crop grown worldwide [1, 2]. Wheat grain is a source of biologically active compounds beneficial to human nutrition and health, including proteins, fatty acids, carbohydrates, dietary fiber, minerals such as calcium, magnesium, phosphorus, potassium, zinc, iron, and copper, vitamins such as thiamin (vitamin B1), riboflavin (vitamin B2), niacin (vitamin B3), pyridoxine (vitamin B6), folic acid (vitamin B9), tocopherol (vitamin E), and phytochemicals such as flavonoids, glycosides, alkaloids, steroids, saponins, terpenoids, and tannins [1–5].

Growing wheat in today's unfavorable climatic conditions, abiotic and biotic stresses reduce wheat yields, which require the development of new environmentally friendly technologies that can prevent environmental pollution and not harm human health [2, 6-10]. Currently, phytohormones, synthetic plant growth regulators, natural biostimulants and biopesticides are increasingly used to increase wheat productivity and adaptation to abiotic and biotic stresses [11-21].

Plant productivity and stress tolerance depends on the development of the root system, which provides plants with organic matter, micro- and macroelements from the soil, affecting the formation and growth of vegetative and reproductive organs of plants [22-24]. As is known, phytohormones auxins and cytokinins play an important role in regulating the growth and development of the root system, shoots, leaves, flowers and seeds of plants, in photosynthesis in plant leaves, as well as in the adaptation of plants to biotic and abiotic stress factors [25-29]. The use of phytohormones has a positive effect on the interaction of plants with soil microorganisms; data on the therapeutic effects of phytohormones on mammals have also been obtained [30].

During plant ontogenesis and under stressful conditions, changes in the metabolism and homeostasis of endogenous plant auxins and cytokinins occur [31-33]. Natural phytohormones auxins and cytokinins or their synthetic analogues, as well as biostimulants, when applied exogenously, are capable of exerting a direct regulatory effect on plant growth or manipulating the biosynthesis and metabolism of endogenous phytohormones, improving plant growth, increasing their productivity and immune-mediated resistance to abiotic and biotic stresses [16-20, 34-43].

In recent years, significant progress has been achieved in the development of new effective and environmentally friendly plant growth regulators based on synthetic low-molecular-weight azaheterocyclic compounds that have a regulatory effect on plant growth similar to the phytohormones auxins and cytokinins [44, 45]. Among the various classes of synthetic azaheterocyclic compounds, pyrimidines, which are used in medicine as therapeutic agents for the treatment of various diseases [46-52], as well as in agriculture as plant growth regulators, herbicides and insecticides [53-60], have the most similar physiological effect to the phytohormones auxins and cytokinins [44, 45].

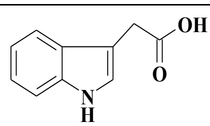
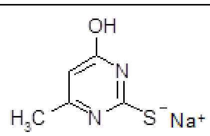
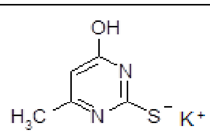
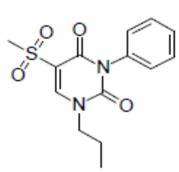
Over the past decade, numerous studies have been conducted devoted to the screening for new auxin- and cytokinin-related substances among synthetic low-molecular-weight azaheterocyclic compounds, pyrimidine derivatives that regulate plant growth [44, 45]. It has been shown that synthetic azaheterocyclic compounds, derivatives of sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur and Kamethur), as well as other pyrimidine derivatives, are capable of exhibiting a broad regulatory effect on various agricultural crops in low concentrations that are non-toxic to human health and the environment, improving plant growth throughout the vegetative phase and increasing their yield [61-74]. A comparative analysis of plant growth regulatory activity indicates that the regulatory effect of these synthetic azaheterocyclic compounds, pyrimidine derivatives is equivalent to, or exceeds, the regulatory effect of auxins and cytokinins on plant growth and development. It is thanks to these unique properties that pyrimidine derivatives can find practical use in agriculture as new effective and environmentally friendly plant growth regulators.

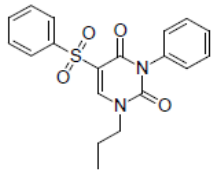
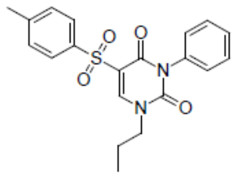
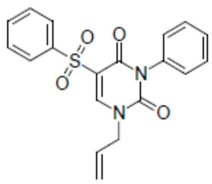
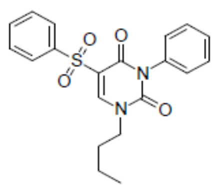
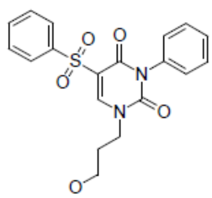
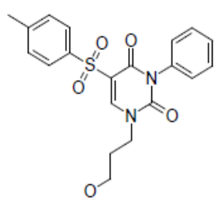
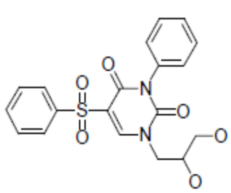
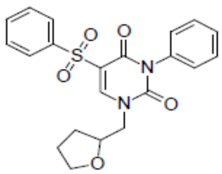
The aim of this work is screening of physiologically active synthetic low-molecular-weight azaheterocyclic compounds, pyrimidine derivatives, capable of regulating the growth and photosynthesis of winter wheat (*T. aestivum* L.) variety Taira.

Materials and Methods

Chemical name and structure of the studied compounds

Synthetic low-molecular-weight azaheterocyclic compounds, derivatives of sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur and Kamethur) were synthesized 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; auxin IAA (1*H*-indol-3-yl) acetic acid) was manufactured by Sigma-Aldrich, USA (Table 1).

Chemical compound	Chemical structure	Chemical name and relative molecular weight (g/mol)
IAA		1*H*-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
1		5-Methanesulfonyl-3-phenyl-1-propyl-1*H*-pyrimidine-2,4-dione MW=308.3586

2		5-Benzenesulfonyl-3-phenyl-1-propyl-1*H*-pyrimidine-2,4-dione MW=370.4303
3		3-Phenyl-1-propyl-5-(toluene-4-sulfonyl)-1*H*-pyrimidine-2,4-dione MW=384.4574
4		1-Allyl-5-benzenesulfonyl-3-phenyl-1*H*-pyrimidine-2,4-dione MW=368.4144
5		5-Benzenesulfonyl-1-butyl-3-phenyl-1*H*-pyrimidine-2,4-dione MW=384.4574
6		5-Benzenesulfonyl-1-(3-hydroxypropyl)-3-phenyl-1*H*-pyrimidine-2,4-dione MW=386.4297
7		1-(3-Hydroxypropyl)-3-phenyl-5-(toluene-4-sulfonyl)-1*H*-pyrimidine-2,4-dione MW=400.4568
8		5-Benzenesulfonyl-1-(2,3-dihydroxypropyl)-3-phenyl-1*H*-pyrimidine-2,4-dione MW=402.4291
9		5-Benzenesulfonyl-3-phenyl-1-(tetrahydrofuran-2-ylmethyl)-1*H*-pyrimidine-2,4-dione MW=412.4680

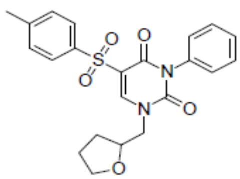
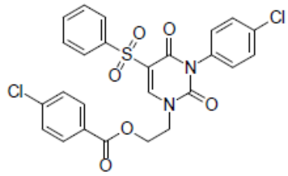
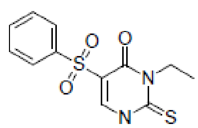
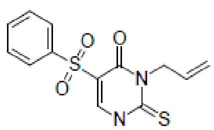
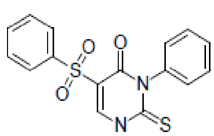
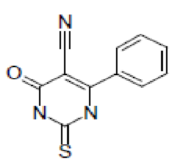
10		3-Phenyl-1-(tetrahydrofuran-2-ylmethyl)-5-(toluene-4-sulfonyl)-1*H*-pyrimidine-2,4-dione MW=426.4950
11		4-Chlorobenzoic acid 2-[5-benzenesulfonyl-3-(4-chlorophenyl)-2,4-dioxo-3,4-dihydro-2*H*-pyrimidin-1-yl]-ethyl ester MW=545.4020
12		5-Benzenesulfonyl-3-ethyl-2-thioxo-2,3-dihydro-1*H*-pyrimidin-4-one MW=296.3690
13		3-Allyl-5-benzenesulfonyl-2-thioxo-2,3-dihydro-1*H*-pyrimidin-4-one MW=308.3802
14		5-Benzenesulfonyl-3-phenyl-2-thioxo-2,3-dihydro-1*H*-pyrimidin-4-one MW=344.4136
15		4-Oxo-6-phenyl-2-thioxo-1,2,3,4-tetrahydro-pyrimidine-5-carbonitrile MW=229.2619

Table 1: Chemical structure of IAA (1*H*-indol-3-yl) acetic acid), sodium salt of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur), potassium salt of 6-methyl-2-mercapto-4-hydroxypyrimidine (Kamethur), and pyrimidine derivatives № 1–15

Plant growing conditions

The seeds of winter wheat (*T. aestivum* L.) variety Taira were sterilized with 1 % $KMnO_4$ solution for 10 min, then treated with 96 % ethanol solution for 1 min, after which they were washed three times with sterile distilled water. After this procedure, seeds were placed in the plastic cuvettes (each containing 20-25 seeds) on the perlite moistened with distilled water (control sample) or water solutions of auxin IAA (1*H*-indol-3-yl)acetic acid or synthetic low-molecular-weight azaheterocyclic compounds, derivatives of sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur and Kamethur), or pyrimidine derivatives (compounds № 1–15) at a concentration of 10^{-6}M (experimental samples). Then seeds were placed in the thermostat for germination in darkness at the temperature 20-22 °C during 48 h. The germinated seeds were placed in a climatic chamber, in which the plants were grown for 4 weeks under a light/dark regime of 16/8 h, a temperature of 20-22 °C, a light intensity of 3000 lux, and an air humidity of 60-80 %. Comparative analysis of plant growth parameters, such as average shoot length (mm), average root length (mm), was performed at the end of the 4-week period according to the methodical manual [75]. Plant growth parameters determined on experimental plants, in comparison with similar parameters of control plants, were expressed as %.

Determination of chlorophyll and carotenoid content

The content of photosynthetic pigments such as chlorophylls and carotenoids (mg/g fresh weight) in wheat leaves was analyzed according to methodological recommendations [76, 77]. 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 $CaCO_3$ (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 Specord M-40 (Carl Zeiss, Germany).

The content of chlorophyll a, chlorophyll b, and carotenoids in plant leaves was calculated in accordance with formula [76, 77]:

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 of extracted from 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 fresh weight), C - concentration of pigments (µg/ml), V - volume of extract (ml), a_1 - sample of leaves (g).

The content of photosynthetic pigments determined in the leaves of experimental wheat plants in relation to control plants was 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 $P\leq0.05$; mean values ± standard deviation (± SD) [78].

Results and Discussion

Regulatory effect of pyrimidine derivatives on wheat growth

A comparative analysis of the regulatory effect of auxin IAA (1*H*-indol-3-yl)acetic acid, synthetic low-molecular-weight azaheterocyclic compounds, derivatives of sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur and Kamethur), and pyrimidine derivatives № 1–15 in a concentration of 10^{-6}M on the growth and development of winter wheat (*T. aestivum* L.) variety Taira was conducted. Wheat growth parameters such as average shoot length (mm), average root length (mm), measured at the end of 4 weeks after seed germination, were compared with those of control wheat grown in distilled water.

The study showed that the growth parameters of wheat shoots and roots under the regulatory effect of derivatives of sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur and Kamethur), or pyrimidine derivatives № 1–15 were similar to or higher than the growth parameters of wheat under the regulatory effect of auxin IAA, and also significantly exceeded the growth parameters of control wheat grown in distilled water (Figure 1).

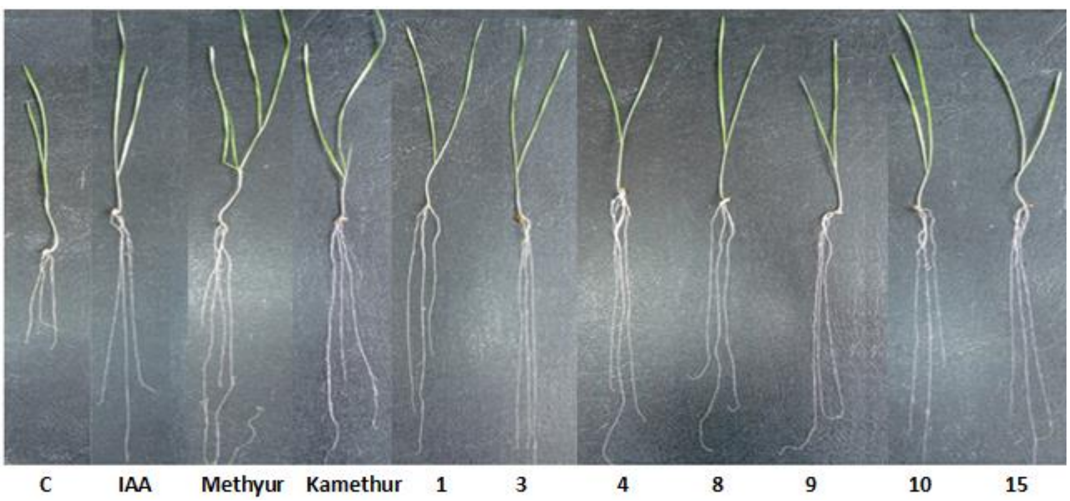


Figure 1: The regulatory effect of auxin IAA, derivatives of sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur and Kamethur), as well as the most physiologically active pyrimidine derivatives № 1, 3, 4, 8, 9, 10, 15 at a concentration of 10^{-6}M on the growth parameters of shoots and roots of 4-week-old winter wheat (*T. aestivum* L.) variety Taira compared to control (C) plants.

It was shown that the highest regulatory effect on the average shoot length (mm) is exhibited by derivative of sodium salt of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur) and pyrimidine derivatives № 4, 5, 6, 8, 9, 10, 11, 13, 14, 15, under the effect of which these parameters increase: by 36.38% - under the effect of Methyur, by 43.5–71.75% - under the effect of pyrimidine derivatives № 4, 5, 6, 8, 9, 10, 11, 13, 14, 15, compared to similar parameters of control plants (Figure 2).

The lower regulatory effect on the average shoot length (mm) is exhibited by auxin IAA, derivative of potassium salt of 6-methyl-2-mercapto-4-hydroxypyrimidine (Kamethur) and pyrimidine derivatives № 1, 2, 3, 7, 12, under the effect of which these parameters increase: by 9.6% - under the effect of IAA, by 20.9% - under the effect of Kamethur, by 12.88–30.85% - under the effect of pyrimidine derivatives № 1, 2, 3, 7, 12, compared to similar parameters of control plants (Figure 2).

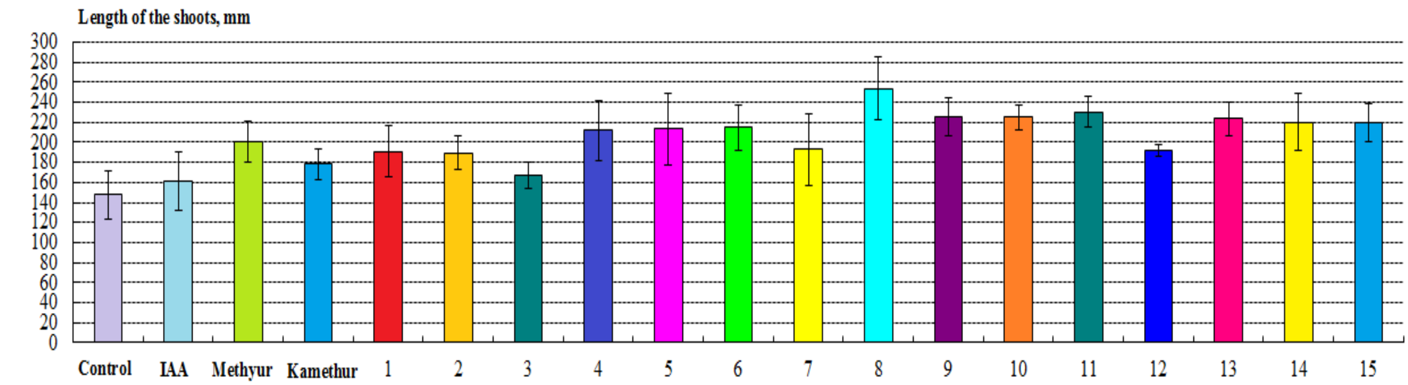


Figure 2: The regulatory effect of auxin IAA, derivatives of sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur and Kamethur), and pyrimidine derivatives № 1-15 at a concentration of 10^{-6}M on the average shoot length (mm) of 4-week-old winter wheat (*T. aestivum* L.) variety Taira compared to control plants.

The highest regulatory effect on the average root length (mm) is exhibited by derivatives of sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur and Kamethur) and pyrimidine derivatives № 1, 3, 4, 9, 10, 15, under the effect of which these parameters increase: by 133.33% - under the effect of Methyur, by 118.61% - under the effect of Kamethur, by 92.56–113.11 % - under the effect of pyrimidine derivatives № 1, 3, 4, 9, 10, 15, compared to similar parameters of control plants (Figure 3).

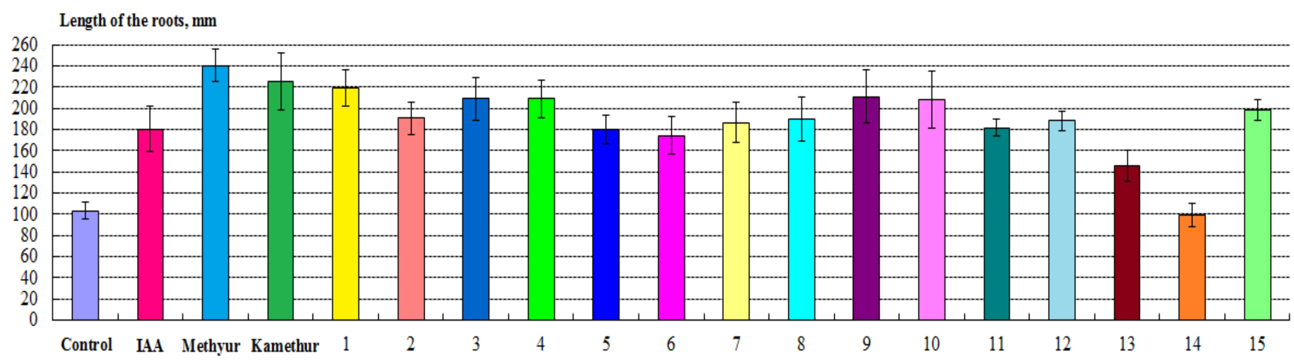


Figure 3: The regulatory effect of auxin IAA, derivatives of sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur and Kamethur), and pyrimidine derivatives № 1-15 at a concentration of 10^{-6}M on the average root length (mm) of 4-week-old winter wheat (*T. aestivum* L.) variety Taira compared to control plants.

The lower regulatory effect on the average root length (mm) is exhibited by auxin IAA and pyrimidine derivatives № 2, 5, 6, 7, 8, 11, 12, 13, 14, under the effect of which these parameters increase: by 75.24% - under the effect of IAA, by 41.59–84.95% - under the effect of pyrimidine derivatives № 2, 5, 6, 7, 8, 11, 12, 13, 14, compared to similar parameters of control plants (Figure 3).

Summarizing the obtained data, it should be noted that the highest regulatory effect on the average shoot length (mm) and average root length (mm) was revealed by derivatives of sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur and Kamethur), and pyrimidine derivatives № 1, 3, 4, 5, 6, 8, 9, 10, 11, 15. Their regulatory effect was similar to or higher than that of auxin IAA. A lower regulatory effect on the average shoot length (mm) and average root length (mm) was found in pyrimidine derivatives № 2, 7, 12, 13, 14

Regulatory effect of pyrimidine derivatives on wheat photosynthesis

A comparative analysis of the regulatory effect of auxin IAA (1*H*-indol-3-yl) acetic acid, synthetic low-molecular-weight azaheterocyclic compounds, derivatives of sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur and Kamethur), and pyrimidine derivatives № 1–15 in a concentration of 10^{-6}M on the photosynthetic parameters of winter wheat (*T. aestivum* L.) variety Taira was carried out. Wheat photosynthetic parameters such as content of chlorophylls and carotenoids (mg/g fresh weight), measured 4 weeks after seed germination, were compared with those of control wheat grown in distilled water.

The highest regulatory effect on the content of chlorophylls and carotenoids in wheat leaves is revealed by derivatives of sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur and Kamethur) and pyrimidine derivatives № 1, 2, 3, 11, 14, 15, under the effect of which the content of chlorophyll a increases: by 23.48% - under the effect of Methyur, by 28.1% - under the effect of Kamethur, by 25.98–65.39% - under the effect of pyrimidine derivatives № 1, 2, 3, 11, 14, 15; the content of chlorophyll b increases: by 23.67% - under the effect of Methyur, by 39.02 % - under the effect of Kamethur, by 25.71–29.01% - under the effect of pyrimidine derivatives № 1, 2, 3; the content of chlorophylls a+b increases: by 23.54% - under the effect of Methyur, by 31.5% - under the effect of Kamethur, by 17.58–44.52% - under the effect of pyrimidine derivatives № 1, 2, 3, 11, 14, 15; the content of carotenoids increases: by 18.98% - under the effect of Methyur, by 48% - under the effect of Kamethur, by 24.74–37.86% - under the effect of pyrimidine derivatives № 1, 2, 11, 14 and 15, compared to similar parameters of control plants (Figure 4).

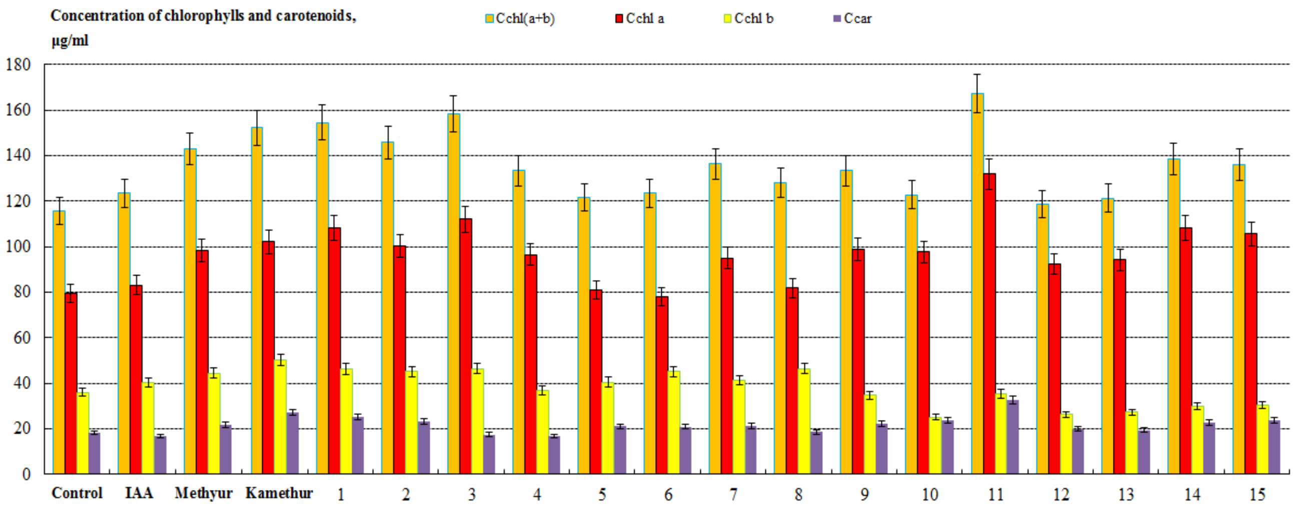


Figure 4. The regulatory effect of auxin IAA, derivatives of sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur and Kamethur), and pyrimidine derivatives № 1-15 at a concentration of 10^{-6}M on the concentration of chlorophylls a, b, a+b and carotenoids (µg/ml) in the leaves of 4-week-old winter wheat (*T. aestivum* L.) variety Taira compared to control plants.

The lower regulatory effect on the content of chlorophylls and carotenoids in wheat leaves is revealed by auxin IAA and pyrimidine derivatives № 4, 5, 6, 7, 8, 9, 10, 12, 13, under the effect of which the content of chlorophyll a increases: by 4.34 % - under the effect of IAA, by 2.57–23.74% - under the effect of pyrimidine derivatives № 4, 5, 6, 7, 8, 9, 10, 12, 13; the content of chlorophyll b increases: by 11.69% - under the effect of IAA, by 2.57–28.89% - under the effect of pyrimidine derivatives № 4, 5, 6, 7, 8, 9, 10, 12, 13; the content of chlorophylls a+b increases: by 6.63% - under the effect of IAA, by 2.63–17.78% - under the effect of pyrimidine derivatives № 4, 5, 6, 7, 8, 9, 10, 12, 13; the content of carotenoids increases: by 2.5–28.81% - under the effect of pyrimidine derivatives № 4, 5, 6, 7, 8, 9, 10, 12, 13, compared to similar parameters of control plants (Figure 4).

Analyzing the relationship between the chemical structure and selectivity of regulatory effect on wheat growth parameters of synthetic compounds, pyrimidine derivatives №1-15, it can be assumed that their effect, similar to or exceeding the effect of the auxin IAA or derivatives of sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur and Kamethur), is associated with the presence of substituents in the chemical structure of these compounds (Table 1).

The synthetic compounds, pyrimidine derivatives № 1, 3, 4, 5, 6, 8, 9, 10, 11, 15 showed the highest regulatory effect on wheat growth parameters, these compounds contain: compound №1 contains methylsulfonyl group in position 5, propyl group in position 1, phenyl group in position 3 of the 1*H*-pyrimidine-2,4-dione ring; compound №3 contains tolylsulfonyl group in position 5, propyl group in position 1, phenyl group in position 3 of the 1*H*-pyrimidine-2,4-dione ring; compound №4 contains allyl substituent in position 1, phenylsulfonyl group in position 5, phenyl group in position 3 of the 1*H*-pyrimidine-2,4-dione ring; compound №5 contains benzenesulfonyl group in position 5, phenyl group in position 3, butyl group in position 1 of the 1*H*-pyrimidine-2,4-dione ring; compound №6 contains benzenesulfonyl group in position 5, phenyl group in position 3, 3-hydroxypropyl group in position 1 of the 1*H*-pyrimidine-2,4-dione ring; compound №8 contains phenylsulfonyl group in position 5, 2,3-dihydroxypropyl group in position 1, phenyl group in position 3 of the 1*H*-pyrimidine-2,4-dione ring; compound №9 contains benzenesulfonyl group in position 5, phenyl group in position 3, tetrahydrofuran-2-ylmethane group in position 1 of the 1*H*-pyrimidine-2,4-dione ring; compound №10 contains *para*-tolylsulfonyl group in position 5, phenyl group in position 1, tetrahydrofuran-2-ylmethyl group in position 1 of the 1*H*-pyrimidine-2,4-dione ring; compound №11 contains phenylsulfonyl group in position 5, 4-chlorobenzoic acid ethyl ester residue in position 3, 4-chlorophenyl group in position 1 of the 2,4-dioxo-3,4-dihydro-2*H*-pyrimidine ring; compound № 15 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.

At the same time, the synthetic compounds, pyrimidine derivatives № 2, 7, 12, 13, 14, showed the lower regulatory effect on wheat growth parameters, these compounds contain: compound №2 contains benzenesulfonyl group in position 5, phenyl group in position 3, propyl group in position 1 of the 1*H*-pyrimidine-2,4-dione ring; compound №7 contains *para*-tolylsulfonyl group in position 5, phenyl group in position 1, 3-hydroxypropyl group in position 1 of the 1*H*-pyrimidine-2,4-dione ring; compound №12 contains a benzenesulfonyl group in position 5, an ethyl group in position 3 of the 2-thioxo-2,3-dihydro-1*H*-pyrimidin-4-one ring; compound №13 contains an allyl substituent in position 3, a phenylsulfonyl group in position 5 of the 2-thioxo-2,3-dihydro-1*H*-pyrimidin-4-one ring; compound №14 contains a phenyl group in position 3, a benzenesulfonyl group in position 5 of the 2-thioxo-2,3-dihydro-1*H*-pyrimidin-4-one ring.

The selected most physiologically active synthetic compounds, pyrimidine derivatives № 1, 3, 4, 5, 6, 8, 9, 10, 11, 15 that stimulate wheat growth and increase photosynthesis are promising for use in agricultural practice.

The results obtained in this work correlate with the data of our previous studies, which indicate that synthetic low-molecular-weight azaheterocyclic compounds, derivatives of sodium and potassium salts of 6-methyl-2-mercapto-4-hydroxypyrimidine (Methyur and Kamethur), and other pyrimidine derivatives, have a stimulating effect on the growth and development of different wheat varieties, similar to the phytohomones auxins and cytokinins, enhance photosynthesis in wheat leaves and increase wheat productivity [63, 64, 79-84]. Based on the obtained data, it was suggested that the regulatory effect of synthetic compounds, pyrimidine derivatives on wheat growth is due to their specific auxin- and cytokinin-like regulatory effect on the proliferation, elongation and differentiation of root and shoot meristem cells during the plant embryogenesis and vegetative phase, improved metabolism, increased protein biosynthesis and prevention of degradation of chlorophylls and carotenoids in plant leaves, which play an important role in plant productivity [25-33, 85-87]. It was also concluded that synthetic compounds, pyrimidine derivatives regulate plant growth similarly to synthetic auxin or cytokinin analogues, through auxin or cytokinin signaling pathways or by increasing the level of endogenous auxins and cytokinins in plants by modulating the activity of key enzymes involved in the biosynthesis, transport, metabolism, conjugation and oxidation of endogenous auxins and cytokinins in plant cells [34-42, 88-99].

Conclusions

A comparative analysis of the regulatory effect of pyrimidine derivatives and auxin IAA on the growth and photosynthesis of wheat (*T. aestivum* L.) variety Taira in the vegetative phase was carried out. A significant intensification of growth of wheat shoots and roots, as well as photosynthesis in wheat leaves, was observed under the regulatory effect of pyrimidine derivatives compared to control wheat grown in distilled water or wheat grown under the regulatory effect of auxin IAA. A correlation has been found between the chemical structure and the selectivity of the regulatory action of synthetic compounds, pyrimidine derivatives. The obtained data indicate a similar effect of pyrimidine derivatives with phytohormones auxins and cytokinins on the growth and photosynthesis of wheat. This fact confirms the prospects of practical application of selected most physiologically active synthetic compounds, pyrimidine derivatives № 1, 3, 4, 5, 6, 8, 9, 10, 11, 15 in agriculture as new wheat growth regulators.

Statement of conflict of interest:

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

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