SciDoc Publishers
Infer, Interpret & Inspire Science

International Journal of Medical Biotechnology & Genetics (IJMBG)
ISSN: 2379-1020

Effect Of Pyrimidine And Pyridine Derivatives On The Growth And Photosynthesis of Pea Microgreens

Research Article

Tsygankova V.A.[1*], Andrusevich Ya.V.[1], Kopich V.M.[1], Voloshchuk I.V.[1], Bondarenko O.M.[2], Pilyo S.G.[1], Klyuchko S. V.[1], Brovarets V.S.[1]

[1] Department for Chemistry of Bioactive Nitrogen-Containing Heterocyclic Compounds, V.P. Kukhar Institute of Bioorganic Chemistry and Petrochemistry, National Academy of Sciences of Ukraine, 1, Academician Kukhar str., 02094, Kyiv-94, Ukraine.
[2] Department of scientific-organizational work and intellectual property, V.P. Kukhar Institute of Bioorganic Chemistry and Petrochemistry, National Academy of Sciences of Ukraine, 1, Academician Kukhar str., 02094, Kyiv-94, Ukraine.

Abstract

The regulatory effect of synthetic plant growth regulators, pyrimidine and pyridine derivatives: Methyur, Kamethur and Ivin, as well as new synthetic compounds, pyrimidine derivatives, on growth and photosynthesis of microgreens of pea (*Pisumsativum* L.) variety Slobozhansky whiskered was studied. The growth-regulating effect of synthetic plant growth regulators Methyur, Kamethur, Ivin, as well as new pyrimidine derivatives, was compared with the growth-regulating effect of phytohormones auxins IAA and NAA. The results obtained showed that synthetic plant growth regulators Methyur, Kamethur and Ivin, as well as new synthetic compounds, pyrimidine derivatives at a concentration of 10^{-7}M, have both auxin-like and cytokinin-like effect on enhancing the growth of shoots and roots of three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered. It was also found that the synthetic plant growth regulators Methyur, Kamethur and Ivin, as well as new synthetic compounds, pyrimidine derivatives at a concentration of 10^{-7}M, exhibit a cytokinin-like effect on the increasing the content of photosynthetic pigments (chlorophylls a, b, a+b and carotenoids) in the leaves of three-week-old microgreens of pea (*Pisum sativum L.*) variety Slobozhansky whiskered. The use of synthetic plant growth regulators Methyur, Kamethur and Ivin, as well as new synthetic pyrimidine derivatives at a concentration of 10^{-7}M to improve the growth of shoots and the roots of pea microgreens, as well as to increase the content of chlorophylls a, b, a+b and carotenoids in pea microgreens is proposed.

Keywords: Pea microgreens; Shoots and Roots, Chlorophylls a, b, a+b and Carotenoids; IAA and NAA; Methyur; Kamethur; Ivin; Pyrimidine and Pyridine Derivatives.

Introduction

The Pea genus (*Pisum* L.) of the family Fabaceae includes wild and cultivated species that are grown in 84 countries around the world [1]. According to FAOSTAT, the world production of dry pea is estimated at 14.360.000 tons [2]. The largest producers and importers of dry pea are Canada, Russia, Ukraine, France and Spain [2]. The use of field peas is diverse, for human nutrition in the countries of Western Europe, Canada, the USA and the Middle East, for animal nutrition in the Balkan region and in the countries of the former USSR [2].

In line with the main goal "European Green Deal" to protect environment, biodiversity and climate and reduce soil, water, and air pollution, pea should be considered as an important crop for a sustainable agriculture [1]. Growing pea promotes accumulation of organic nitrogen and carbon in the soil, which reduces the use of mineral fertilizers and minimizes their accumulation in soil and water [1]. Pea can be used as a catch crop in cereal crop rotations, as it is resistant to cereal diseases and pests [1].

Vegetable pea (*Pisum sativum* L.) is one of the main legumes in world agriculture [3]. According to the FAO, among the varieties of vegetable pea, the most cultivated varieties are green pea (mar-

***Corresponding Author**:
Tsygankova Victoria Anatolyivna,
Department for Chemistry of Bioactive Nitrogen-Containing Heterocyclic Compounds, V.P. Kukhar Institute of Bioorganic Chemistry and Petrochemistry, National Academy of Sciences of Ukraine, 1, Academician Kukhar str., 02094, Kyiv-94, Ukraine.
Tel: 0924621018
E-mail: vTsygankova@ukr.net

Received: July 11, 2023
Accepted: August 21, 2023
Published: September 07, 2023

Citation: Tsygankova V.A., Andrusevich Ya.V., Kopich V.M., Voloshchuk I.V., Bondarenko O.M., Pilyo S.G., Klyuchko S.V., Brovarets V.S. Effect Of Pyrimidine And Pyridine Derivatives On The Growth And Photosynthesis Of Pea Microgreens. *Int J Med Biotechnol Genetics.* 2023;S1:02:003:15-22.

rowfat and sugar varieties) and shell pea, with an annual production of more than 17 and 11 million tons worldwide [3].

Pea seeds have a high nutritional value, they are used as a source of protein (20 - 36 %), easily digestible starch (29 - 54 %), carbohydrates (4 - 10 %), fat (0.7 - 1.6 %), vitamins (A, C, B1, B2, B3, B4, B6, B9, PP, E, K), macroelements and microelements (potassium, phosphorus, magnesium, calcium, iron, zinc, manganese, copper), dietary fibers, omega-3 and omega-6 fatty acids [1-5].

Pea microgreens are very popular in dietary nutrition, as they are an excellent source of the following substances: amino acids, vitamins A, B, C, E and K, lutein, polysaccharides, polyphenols, chlorophyll, calcium, iron, magnesium, niacin, phosphorus, potassium [6, 7]. Pea microgreens, enriched with biologically active substances that have anti-inflammatory, antiviral, antioxidant, immunomodulatory properties, should be considered as a sprouted vegetable that is beneficial to human health [7].

The technology for growing pea microgreens is economically inexpensive due to the small growing area, short plant growth cycle and low production cost [7]. Many factors influence the microgreens growth, biomass production, and nutritional quality, including temperature, air humidity, photoperiod, light intensity and quality, the type of medium, fertilization, post-harvest handling, and risks of bacterial colonization of microgreens [7-10].

The most promising and topical issue is the possibility of using phytohormones and synthetic plant growth regulators to increase the growth of pea microgreens and biomass production, as well as improve nutritional quality. Our previous studies have shown a high phytohormone-like stimulating effect of the synthetic plant growth regulators based on synthetic pyrimidine and pyridine derivatives: Methyur, Kamethur and Ivin, as well as new synthetic compounds, pyrimidine and pyridine derivatives on growth, biomass production and photosynthesis of microgreens of various crops such as maize, barley, sorghum, chickpea, wheat, sunflower, flax, tomato and lettuce [11-21].

Based on the results of our previous studies, the aim of this work is to study the regulatory effect of synthetic plant growth regulators, pyrimidine and pyridine derivatives: Methyur, Kamethur and Ivin, as well as new synthetic compounds, pyrimidine derivatives, on growth and photosynthesis of microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered.

Materials and Methods

Chemical structures of the studied compounds: Chemical structures of the synthetic plant growth regulators, pyrimidine and pyridine derivatives: Methyur, Kamethur, Ivin, as well as new pyrimidine derivatives, compounds № 1 – 7, 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, are given in Table 1.

The growth-regulating effect of synthetic plant growth regulators Methyur, Kamethur, Ivin, as well as new pyrimidine derivatives, was compared with the growth-regulating effect of the phytohormones auxins IAA and NAA manufactured by Sigma-Aldrich, USA (Table 1).

Conditions for growing pea microgreens: To growth microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered, seeds were sterilized with 1% $KMnO_4$ solution for 3 min, then treated with 96% ethanol solution for 1 min, and washed three times with sterile distilled water. In control samples, pea seeds were treated with distilled water, in experimental samples, pea seeds were treated with water solutions of auxins IAA or NAA, or with each of the plant growth regulators, pyrimidine and pyridine derivatives: Methyur, Kamethur, Ivin, or with each of the new synthetic pyrimidine derivatives, compounds № 1 – 7 at a concentration of 10^{-7}M. After this procedure, the treated pea seeds were placed in cuvettes (15 seeds each), supplemented with perlite, and incubated in a thermostat in the dark at a temperature of 22-24°C for 48 hours. Then, the cuvettes with seeds were placed in a climatic chamber, where pea microgreen were grown for three weeks in the light/dark regime of 16/8 hours, at a temperature of 22-24°C, a light intensity of 3000 lux and an air humidity of 60-80 %. Growth parameters of three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered (average length of shoots and roots (cm), average number of roots (pcs)) were measured according to the method [22].

Determination of the content of photosynthetic pigments in pea microgreens: Determination of the content of photosynthetic pigments (chlorophyll a, chlorophyll b, chlorophylls a+b and carotenoids) in the leaves of microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered was carried out according to the method [23, 24]. To carry out the extraction of photosynthetic pigments we homogenized a sample (500 mg) of pea 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, chlorophylls a+b and carotenoids 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 [23, 24]:

$$C_{chl\,a} = 13.36 \times A664.2 - 5.19 \times A648.6,$$
$$C_{chl\,b} = 27.43 \times A648.6 - 8.12A \times 664.2,$$
$$C_{chl\,(a+b)} = 5.24 \times A664.2 + 22.24 \times A648.6,$$
$$C_{car} = (1000 \times A470 - 2.13 \times C_{chl\,a} - 97.64 \times C_{chlb})/209,$$

Where,

Cchl a– concentration of chlorophyll a (μg/ml), Cchl b – concentration of chlorophyll b (μg/ml), Cchl (a+b)– concentration of chlorophylls a and 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 (in %) was calculated as the ratio between the parameters of experimental pea plants treated with auxin IAA, or plant growth regulators Methyur, Kamethur, Ivin, or new synthetic pyrimidine derivatives, compounds № 1 – 7 at a concentration of 10^{-7}M and similar parameters of control pea plants treated with distilled water.

Statistical Analysis: 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≤0.05; mean values ± standard deviation (± SD) [25].

Results and Discussion

Effect of pyrimidine and pyridine derivatives on the growth of shoots and roots of pea microgreens: It is known that the phytohormones auxins and cytokinins play a key role in controlling the formation and growth of plant root and shoot meristems [26]. Among the natural phytohormones, auxin promotes the growth of plant roots, while cytokinin has a more specific stimulating effect on the growth of plant shoots [27-30].

The regulatory effect of both natural auxins and cytokinins or their synthetic analogues on the elongation, division and differentiation of plant cells, the formation and growth of plant tissues and organs varies depending on the ratio of their active concentrations.As a rule, high concentrations of auxins and low concentrations of cytokinins stimulate the growth of the plant root system, and vice versa, low concentrations of auxins and high concentrations of cytokinins stimulate the growth of plant shoots [31].

The results obtained in this work showed that synthetic plant growth regulators based on synthetic pyrimidine and pyridine derivatives: Methyur, Kamethur and Ivin, as well as new synthetic compounds, pyrimidine derivatives, have both auxin-like and cytokinin-like stimulating effect on the growth and development of shoots and roots of three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered.

The growth-regulating effect of Methyur, Kamethur and Ivin, as well as the most active new synthetic pyrimidine derivatives, compounds № 1, 2, 3, 4 and 7, was similar or higher than the growth-regulating effect of auxins IAA and NAA.

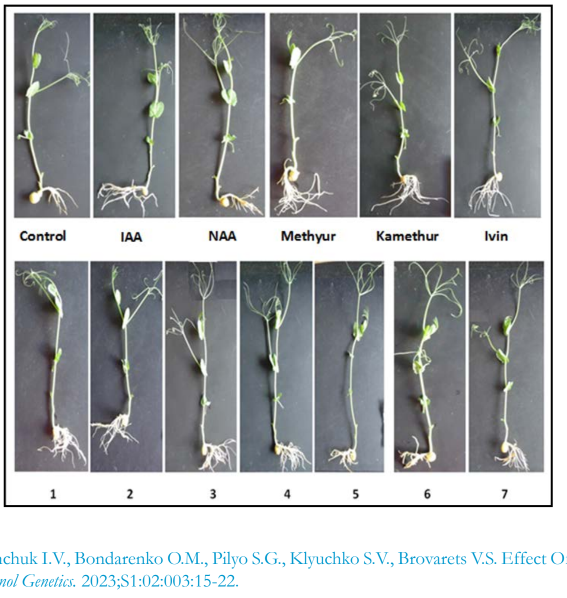
Growth parameters of experimental three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered,treated with plant growth regulators: Methyur, Kamethur, Ivin, or each of the new pyrimidine derivatives, compounds № 1, 2, 3, 4 and 7 at a concentration of 10^{-7}M, was significantly higher than similar parameters of the control three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered, treated with distilled water (Fig. 1).

According to the parameters of average length of shoots (cm), the plant growth regulators Methyur, Kamethur and Ivin, as well as new synthetic pyrimidine derivatives, compounds № 1, 2, 3, 4 and 7 showed the highest growth-regulating effect (Fig. 2). The parameters of the average length of shoots (cm) increased: by 118.39% - when treated with Methyur, by 103.61% - when treated with Kamethur, by 119.16% - when treated with Ivin, by 79.31–104.93 % - when treated with compounds № 1, 2, 3, 4 and 7, respectively, compared with the control three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered (Fig. 2).

Auxins IAA and NAA had a similar growth-regulating effect. The parameters of the average length of shoots (cm) increased by 52.64 % - when treated with IAA, and by 100.99 % - when treated with NAA, respectively, compared with the control three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered (Fig. 2).

New synthetic pyrimidine derivatives, compounds № 5 and 6 showed a lower growth-regulating effect, the parameters of the average length of shoots (cm) increased by 23.22 – 35.42 % -

Figure 1. The effect of auxins IAA and NAA, plant growth regulators Methyur, Kamethur and Ivin, as well as new synthetic pyrimidine derivatives (compounds № 1 – 7) at a concentration of 10^{-7}M on the growth and development of shoots and roots of three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered, compared with the control.



when treated with compounds № 5 and 6, respectively, compared with the control three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered (Fig. 2).

According to the parameters of average length of roots (cm), the plant growth regulators Methyur, Kamethur and Ivin, as well as new synthetic pyrimidine derivatives, compounds № 1, 2, 4 and 7 showed the highest growth-regulating effect (Fig. 3). The parameters of the average length of roots (cm) increased: by 151.43% - when treated with Methyur, by 186.67% - when treated with Kamethur, by 63.08 % - when treated with Ivin, by 44.62-140 % - when treated with compounds № 1, 2, 4 and 7, respectively, compared with the control three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered (Fig. 3).

Auxin IAA had a similar growth-regulating effect. The parameters of the average length of roots (cm) increased: by 122.22 % - when treated with IAA, respectively, compared with the control three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered (Fig. 3). The data obtained indicate that auxin IAA showed a high stimulating effect on the growth of the main roots of pea microgreen. To a lesser extent, this applies to auxins, which, in some plant species, are known to suppress the elongation of the main roots, slowing down their growth [32, 33]. This, apparently, is associated with the use of auxin IAA at a low concentration of 10^{-7}M, which does not suppress the growth of main roots in length.

Auxin NAA and new synthetic pyrimidine derivatives, compounds № 3, 5 and 6 did not show growth-regulating effect, parameters of the average length of roots (cm) did not have a statistically significant difference with the control or were lower than similar parameters of the control three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered (Fig. 3).

According to the parameters of average number of roots (pcs), the plant growth regulators Methyur, Kamethur and Ivin, as well as new synthetic pyrimidine derivatives, compounds № 1, 2, 3, 4 and 7 showed the highest growth-regulating effect (Fig. 4). The parameters of the average number of roots (pcs) increased: by 130.86% - when treated with Methyur, by 161.33% - when treated with Kamethur, by 129.33% - when treated with Ivin, by 69.14-168.57 % - when treated with compounds № 1, 2, 3, 4 and 7, respectively, compared with the control three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered (Fig. 4).

Auxins IAA and NAA had a similar growth-regulating effect. The parameters of the average number of roots (pcs) increased by 125.78 % - when treated with IAA and by 113.33 % - when treated with NAA, respectively, compared with the control three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered (Fig. 4). The data obtained indicate that auxins IAA and NAA showed a high stimulating effect on the growth of the lateral roots of pea microgreen.This is characteristic of auxins, which, are known to stimulate the growth of lateral roots [32, 33]. A new synthetic pyrimidine derivative, compound № 5, showed a lower growth-regulating effect. The parameters of the average number of roots (pcs) increased by 26.4 % - when treated with compound № 5, respectively, compared with the control three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered (Fig. 4).

A new synthetic pyrimidine derivative, compound № 6, did not show a growth-regulating effect. The parameters of the average number of roots (pcs) were lower than similar parameters of the control three-week-old microgreens of pea (*Pisum sativum* L.) va-

Figure 2. The effect of auxins IAA and NAA, plant growth regulators Methyur, Kamethur and Ivin, as well as new synthetic pyrimidine derivatives (compounds № 1 – 7) at a concentration of 10^{-7}M on the average length of shoots (cm) of three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered, compared with the control (C).

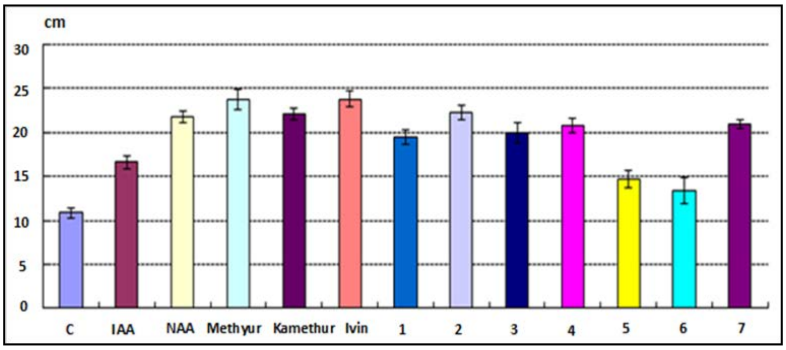


Figure 3. The effect of auxins IAA and NAA, plant growth regulators Methyur, Kamethur and Ivin, as well as new synthetic pyrimidine derivatives (compounds № 1 – 7) at a concentration of 10^{-7}M on the average length of roots (cm) of three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered, compared with the control (C).

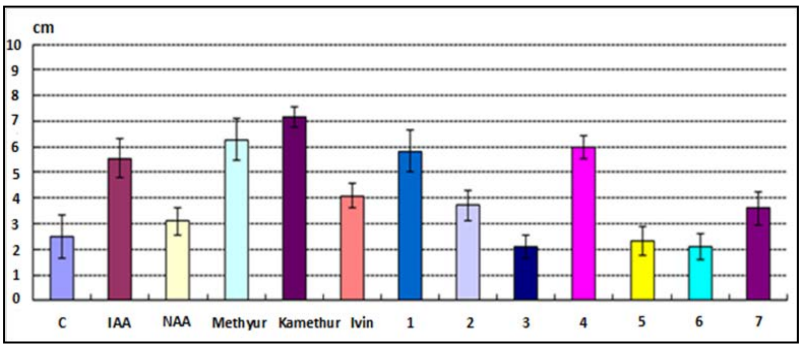
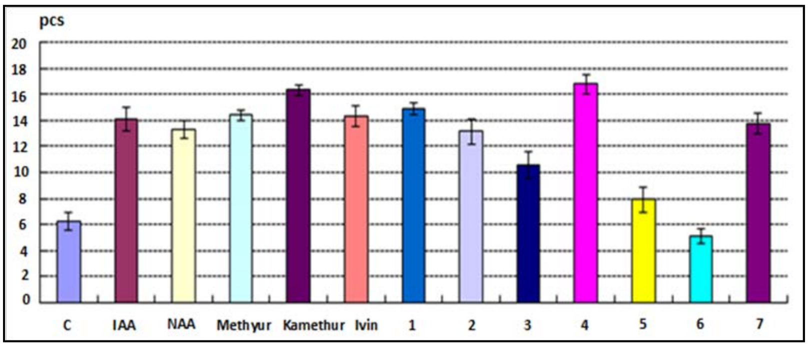


Figure 4. The effect of auxins IAA and NAA, plant growth regulators Methyur, Kamethur and Ivin, as well as new synthetic pyrimidine derivatives (compounds № 1 – 7) at a concentration of 10^{-7}M on the average number of roots (pcs) of three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered, compared with the control (C).



riety Slobozhansky whiskered (Fig. 4).

Summarizing the data obtained, it is obvious that the high growth-regulating effect of synthetic plant growth regulators, pyrimidine and pyridine derivatives: Methyur, Kamethur and Ivin, as well as new synthetic pyrimidine derivatives, compounds № 1, 2, 3, 4 and 7, is associated with their auxin-like and cytokinin-like effect on the processes of proliferation, elongation and differentiation of plant cells [26-35]. As a result, the growth and development of shoots and roots of microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered are enhanced.

The data of a comparative analysis of the relationship between the chemical structure and biological activity of new synthetic pyrimidine derivatives indicate that the high plant growth-regulating activity of compounds № 1, 2, 3, 4 and 7 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 № 4 contains an isopropyl substituent in position 2, a hydroxyl group in position 4, and a methyl group in position 6; compound № 7 contains a benzylthio group in position 2 and a hydroxyl group in position 4 (Table 1).

The decrease of plant growth-regulating effect of new synthetic pyrimidine derivatives, compounds №5 and 6, can be explained by the presence of substituents in the chemical structure of these compounds: compound № 5 is the sodium salt of 4-hydroxypyrimidine-2-thiolate; compound № 6 contains a methylthio group in position 2 and a hydroxyl group in position 4 (Table 1).

It should also be noted that Ivin contains the macronutrient nitrogen, Kamethur contains the macronutrients nitrogen, potassium and sulfur, while plant growth regulator Methyur and synthetic compounds № 1, 2, 3 and 7 contain the macronutrients nitrogen and sulfur, which are necessary for the growth of pea plants and take an important part in the regulation of metabolic processes in pea plant cells. Plant growth regulator Methyur also contains the chemical element sodium, which plays an important role in plant adaptation to salt and osmotic stress [36-38].

Effect of pyrimidine and pyridine derivatives on the content of photosynthetic pigments in pea microgreens: As is known, phytohormones cytokinins play a key role in the regulation of photosynthesis and slowing down the degradation of chlorophylls, which are the main indicators of plant productivity [23, 24, 29, 35].

In this work, the cytokinin-like regulatory effect of the synthetic plant growth regulators, pyridine and pyrimidine derivatives: Ivin, Methyur and Kamethur, as well as new synthetic compounds, pyrimidine derivatives on the content of photosynthetic pigments (chlorophylls a, b, a+b and carotenoids) in the leaves of three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered was studied.The conducted studies showed that the synthetic plant growth regulators Ivin, Methyur and Kamethur, as well as new synthetic pyrimidine derivatives, compounds № 1, 3, 6 and 7, exhibit the highest cytokinin-like effect.

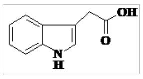
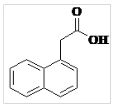
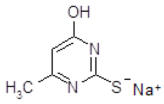
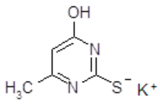
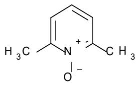
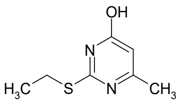
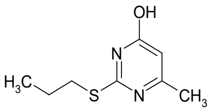
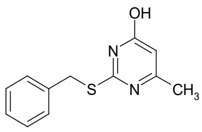
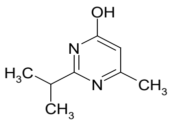
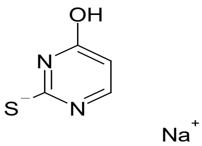
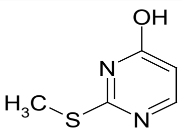
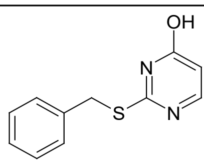
The content of chlorophyll a (μg/ml) in the leaves of three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered increased: by 3.47% - when treated with Ivin, by 29.71 % - when treated with Methyur, by 63.55% - when treated with Kamethur, by 6.09-30.96 % - when treated with compounds № 1, 3, 6 and 7, respectively, compared with the control three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered (Fig. 5).

The content of chlorophyll b (μg/ml) in the leaves of three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered increased: by 13.54% - when treated with Ivin, by 55.34% - when treated with Methyur, by 91.63% - when treated with Kamethur, by 28.32-77.66 % - when treated with compounds № 1, 3, 6 and 7, respectively, compared with the control three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered (Fig. 5).

The content of chlorophylls a+b (μg/ml) in the leaves of three -week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered increased: by 6.44% - when treated with Ivin, by 37.26% - when treated with Methyur, by 71.84% - when treated with Kamethur, by 12.65–44.74 % - when treated with compounds № 1, 3, 6 and 7, respectively, compared with the control three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered (Fig. 5).

The content of carotenoids (μg/ml) in the leaves of three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered increased:by 3.03 % - when treated with Ivin, by 7.65% - when treated with Methyur, by 32.07% - when treated

Table 1. Chemical structure and relative molecular weight of auxins IAA and NAA, plant growth regulators Methyur, Kamethur and Ivin, and new pyrimidine derivatives.

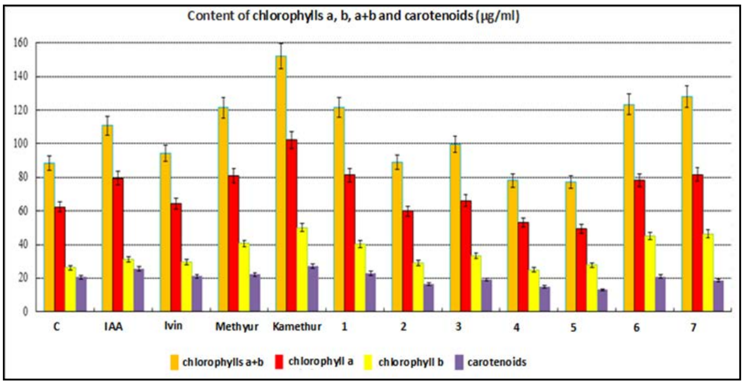
Chemical compound №	Chemical structure	Chemical name and relative molecular weight (g/mol)
IAA		1*H*-Indol-3-ylacetic acid MW=175.19
NAA		1-naphthylacetic acid MW=186.21
Methyur		Sodium salt of 6-methyl-2-mercapto-4-hydroxypyrimidine MW=165.17
Kamethur		Potassium salt of 6-methyl-2-mercapto-4-hydroxypyrimidine 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

with Kamethur, by 11.27% - when treated with compound № 1, respectively, compared with the control three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered (Fig. 5).

Auxin IAA had a similar effect on the content of photosynthetic pigments in the leaves of three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered, the content of chlorophyll a (µg/ml) increased by 27.19 %, the content of chlorophyll b (µg/ml) increased by 19.95 %, the content of chlorophylls a+b (µg/ml) increased by 26.06 %, the content of carotenoids (µg/ml) increased by 24.09 %, respectively, compared with the control three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered (Fig. 5).

New synthetic pyrimidine derivatives, compounds № 2, 4 and 5,

Figure 5. The effect of auxin IAA, plant growth regulators Ivin, Methyur and Kamethur, as well as new synthetic pyrimidine derivatives (compounds № 1 – 7) at a concentration of 10^{-7}M on the content of chlorophylls a, b, a+b and carotenoids (µg/ml) in the leaves of three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered, compared with the control (C).



did not show stimulating effect, the content of photosynthetic pigments did not have a statistically significant difference with the control or was lower than similar parameters of the control three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered (Fig. 5).

It should be noted that the absence of an increase or decrease in the content of chlorophylls a, b, a+b and carotenoids (µg/ml) in the leaves of three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered treated with compounds № 2 and 4 may be due to their effecton enhancing the growth of shoots and increasing their fresh weight.

Thus, the obtained results confirmed the positive effect of synthetic plant growth regulators, pyridine and pyrimidine derivatives: Ivin, Methyur and Kamethur, as well as new synthetic pyrimidine derivatives, compounds № 1, 3, 6 and 7 on increasing the content of photosynthetic pigments (chlorophylls a, b, a+b and carotenoids), which play a key role in photosynthesis and ensuring plant productivity [23, 24], in the leaves of three-week-old microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered.

Probably, the increase in the content of photosynthetic pigments is associated with the cytokinin-like regulatory effect of the studied synthetic plant growth regulators and new pyrimidine derivatives on the delay in leaf senescence (controlled by senescence-associated genes (SAGs)) by maintaining active de novo chlorophyll biosynthesis and slowing down chloroplast disassembly and degradation of nucleic acids, proteins, lipids in plant cells [29, 35, 39].

Conclusion

The results obtained in this work indicate the prospects for the use of synthetic plant growth regulators, pyrimidine and pyridine derivatives: Methyur, Kamethur and Ivin, as well as new synthetic pyrimidine derivatives, compounds № 1, 2, 3, 4 and 7 at a concentration of 10^{-7}M to improve the growth of shoots and the roots of microgreens of pea (*Pisum sativum* L.) variety Slobozhansky whiskered, as well as to increase the content of chlorophylls a, b, a+b and carotenoids in pea microgreens.

Statement of Conflict of Interest. The authors are declared that they have no conflict with this research article.

References

[1]. Janusauskaite D. Productivity of Three Pea (*Pisum sativum* L.) Varieties as Influenced by Nutrient Supply and Meteorological Conditions in Boreal Environmental Zone. Plants. 2023 May 9;12(10):1938.
[2]. Milošević B, Mihailović V, Karagić Đ, Vasiljević S, Milić D, Petrović G, et al. Grain yield potential of spring dry pea varieties. Acta Agriculturae Serbica. 2020;25(50):153-7.
[3]. Poltoretskyi S, Karpenko V, Liubych V, Poltoretska N, Bilonozhko V, Demydas H. Morphological and ecological features of green pea (*Pisum sativum* L.). Ukrainian Journal of Ecology. 2022;12(8):12-9.
[4]. Svinarchuk O, Bezruchko I. Market of Plant Varieties in Ukraine: Green Pea (*Pisum sativum* L *partim*). Plant Varieties Studying and Protection. 2012;1(15):48-57.
[5]. Kaigorodova IM, Ushakov VA, Golubkina NA, Kotlyar IP, Pronina EP, Antoshkina MS. Nutritional value, quality of raw materials and food value of vegetable pea culture (*Pisum sativum* L.). Vegetable crops of Russia. 2022;3:16-32.
[6]. E-source[Internet]. Pea microgreens nutritional data. [cited 2023Aug 22]. Available from: https://urbanfarming.com/pea-microgreens/
[7]. Zhang S, Guo X, Li J, Zhang Y, Yang Y, Zheng W, et al. Effects of light-emitting diode spectral combinations on growth and quality of pea sprouts under long photoperiod. Front Plant Sci. 2022 Sep 7;13:978462. PubMed PMID: 36161035.
[8]. Abaajeh AR, Kingston CE, Harty M. Environmental factors influencing the growth and pathogenicity of microgreens bound for the market: a review. Renewable Agriculture and Food Systems. 2023;38:e12.
[9]. Bantis F. Light Spectrum Differentially Affects the Yield and Phytochemical Content of Microgreen Vegetables in a Plant Factory. Plants (Basel). 2021 Oct 14;10(10):2182. PubMed PMID: 34685989.
[10]. Kong Y, Llewellyn D, Zheng Y. Response of growth, yield, and quality of pea shoots to supplemental light-emitting diode lighting during winter greenhouse production. Canadian Journal of Plant Science. 2018 Jan 12;98(3):732-40.
[11]. Tsygankova V, Andrusevich Y, Shtompel O, Hurenko A, Solomyannyj R, Mrug G, etal. Stimulating effect of five and six-membered heterocyclic compounds on seed germination and vegetative growth of maize (*Zea mays* L.). International Journal of Biology Research. 2016;1(4):1-4.
[12]. Tsygankova VA, Andrusevich Ya V, Shtompel OI, Shablykin OV, Hurenko AO, et al. Auxin-like effect of derivatives of pyrimidine, pyrazole, isoflavones, pyridine, oxazolo pyrimidine and oxazole on acceleration of vegetative growth of flax. International Journal of Pharm Tech Research. 2018;11(3):274-286.
[13]. Tsygankova VA, Andrysevich YV, Shtompel OI, Kopich VM, Kluchko SV, Brovarets VS. Using Pyrimidine Derivatives - Sodium Salt of Methyur and Potassium Salt of Methyur, to Intensify the Growth of Corn. Patent of Ukraine 130921. 12 December 2018.
[14]. Tsygankova V, Andrusevich Y, Shtompel O, Kopich V, Solomyanny R, Bondarenko O, et al. Phytohormone-like effect of pyrimidine derivatives on regulation of vegetative growth of tomato. International Journal of Botany Studies. 2018; 3(2): 91-102.
[15]. Tsygankova VA, Voloshchuk IV, Andrusevich YV, Shtompel OI, Kopich VM, Klyuchko SV, et al. Using pyrimidine and pyridine derivatives for regu-

lation of growth and development of barley plants. Proceedings of the Innovative Development of Science and Education; ISGT Publishing House: Athens, Greece. 2020:52-68.
[16]. Tsygankova VA, Andrusevich YaV, Mirolyubov OV, Shtompel OI, Kopich VM, Klyuchko SV. Application of sodium and potassium salts of Methyur for growing lettuce (*Lactuca sativa* L.) in hydroponic conditions. Proceedings of the V International Scientific and Practical Conference.Osaka, Japan. 2020;820-833.
[17]. Tsygankova V, Voloshchuk I, AndrusevichYa, Kopich V, Shtompel O, Klyuchko S, et al. New growth regulators of sorghum plants based on synthetic pyrimidine and pyridine derivatives, Proceedings of the 12th International scientific and practical conference "World science: problems, prospects and innovations". Perfect Publishing; Toronto, Canada. 2021;498-512.
[18]. Tsygankova VA, Voloshchuk IV, Andrusevich Ya V, Kopich VM, Pilyo SG, Klyuchko SV, et al. Pyrimidine derivatives as analogues of plant hormones for intensification of wheat growth during the vegetation period.J Adv Biol. 2022;15:1-10.
[19]. Tsygankova VA, Andreev AM, Andrusevich YaV, Pilyo SG, Klyuchko SV, Brovarets VS. Use Of Synthetic Plant Growth Regulators In Combination With Fertilizers to Improve Wheat Growth. Int J Med Biotechnol Genetics.2023;S1:02:002:9-14.
[20]. Tsygankova VA, Andrusevich YaV, Kopich VM, Voloshchuk IV, Pilyo SG, Klyuchko SV. Application of pyrimidine and pyridine derivatives for regulation of chickpea (*Cicer arietinum L.*) growth.IJISRT.2023;8(6):19-28.
[21]. Tsygankova VA, Andreev AM, AndrusevichYa V, Pilyo SG, Brovarets VS. Effect of plant growth regulators and fertilizers on the vegetative growth of sunflower (*Helianthus annuus* L.). The scientific heritage. 2023;116(116):3-9.
[22]. Voytsehovska OV, Kapustyan AV, Kosik OI, Musienko MM, Olkhovich OP, Panyuta OO, et al. Plant Physiology: Praktykum. Lutsk: Teren. 2010;420.
[23]. Harmut AJ. Chlorophylls and carotenoids: pigments of photosynthetic membranes. Methods Enzymol.. 1987;148:350-83.
[24]. Lichtenthaler HK, Buschmann C. Chlorophylls and carotenoids: Measurement and characterization by UV-VIS spectroscopy. Current protocols in food analytical chemistry. 2001 Aug;1(1):F4-3.
[25]. Bang H, Zhou XK, van Epps HL, Mazumdar M. Statistical Methods in Molecular Biology. Series: Methods in molecular biology. New York: Humana press. 2010;13(620):636.
[26]. Su YH, Liu YB, Zhang XS. Auxin-cytokinin interaction regulates meristem development. Mol Plant. 2011 Jul;4(4):616-25. PubMed PMID: 21357646.
[27]. Zhao Y. Auxin biosynthesis and its role in plant development. Annu Rev Plant Biol. 2010;61:49-64. PubMed PMID: 20192736.
[28]. Kieber JJ, Schaller GE. Cytokinin signaling in plant development. Development. 2018 Feb 27;145(4):dev149344. PubMed PMID: 29487105.
[29]. Wu W, Du K, Kang X, Wei H. The diverse roles of cytokinins in regulating leaf development. Hortic Res. 2021 Jun 1;8(1):118. PubMed PMID: 34059666.
[30]. Kurepa J, Smalle JA. Auxin/Cytokinin Antagonistic Control of the Shoot/Root Growth Ratio and Its Relevance for Adaptation to Drought and Nutrient Deficiency Stresses. Int J Mol Sci. 2022 Feb 9;23(4):1933. PubMed PMID: 35216049.
[31]. Cammarata J, Roeder AHK, Scanlon MJ. The ratio of auxin to cytokinin controls leaf development and meristem initiation in Physcomitrium patens. J Exp Bot. 2023 Jul 27:erad299. PubMed PMID: 37498739.
[32]. Woodward AW, Bartel B. Auxin: regulation, action, and interaction. Ann Bot. 2005 Apr;95(5):707-35. PubMed PMID: 15749753.
[33]. Cleland RE. Auxin and cell elongation. In: Plant hormones. Springer: Dordrecht. 1995;214-227.
[34]. Lavy M, Estelle M. Mechanisms of auxin signaling. Development. 2016 Sep 15;143(18):3226-9. PubMed PMID: 27624827.
[35]. Tsygankova VA, Andrusevich YV, Shtompel OI, Solomyanny RM, Hurenko AO, Frasinyuk MS, et al. New Auxin and Cytokinin Related Compounds Based on Synthetic Low Molecular Weight Heterocycles. In Auxins, Cytokinins and Gibberellins Signaling in Plants 2022 Aug 19. pp. 353-377. Cham: Springer International Publishing.
[36]. Bilyavska NO, Voloshina NYu, Topchii NM, Konturska OO, Palladina TO.Effects of salt and osmotic stresses and Methyure on foliar photosynthetic apparatus in maize. Bulletin of Kharkiv National Agrarian University, Series: Biology.2009;3:35-42.
[37]. Palladina TO, Konturska OO. Dependence of preparation Metiure adaptogenic effect on plants under salt stress conditions from its molecular structure. Biotechnologia Acta. 2012;5(1):115-20.
[38]. Rudnytska MV, Palladina TA. Effect of preparations Methyure and Ivine on Ca^{2+}-ATPases activity in plasma and vacuolar membrane of corn seedling roots under salt stress conditions. Ukr Biochem J. 2017 Jan-Feb;89(1):76-81. PubMed PMID: 29236392.
[39]. Huang P, Li Z, Guo H. New Advances in the Regulation of Leaf Senescence by Classical and Peptide Hormones. Front Plant Sci. 2022 Jun 28;13:923136. PubMed PMID: 35837465.