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INTENSIFICATION OF VEGETATIVE GROWTH OF CUCUMBER BY DERIVATIVES OF [1,3]OXAZOLO[5,4-*D*]PYRIMIDINE AND N-SULFONYL SUBSTITUTED OF 1,3-OXAZOLE

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ABSTRACT: The elaboration of new plant growth regulators (PGRs) as effective substituents of plant hormones to improve the growth and increase the yield of vegetable crops is an important task for successful development of modern agriculture. Cucumber (*Cucumis sativus* L.) belongs to important food and medicinal plants cultivated in different countries of the world. Our work was aimed to study of regulatory effect of synthetic low molecular weight heterocyclic compounds (LMWHC), derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine and N-sulfonyl substituted of 1,3-oxazole on vegetative growth of cucumber plants (*Cucumis sativus* L.) of cultivar Dzherelo. The obtained results showed that some from tested LMWHC used at concentration 10^{-9}M revealed high auxin-like and cytokinin-like stimulating effect on germination of seeds and acceleration of growth of cucumber seedlings grown for 24 days in the laboratory conditions. The relationship between chemical structure and plant growth regulatory activity of synthetic LMWHC was observed. The practical application of synthetic LMWHC derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine and N-sulfonyl substituted of 1,3-oxazole as new effective regulators of growth of cucumber plants was proposed.

KEYWORDS: cucumber (*Cucumis sativus* L.), auxin IAA, oxazolopyrimidine, oxazole, plant growth regulators.

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1. INTRODUCTION

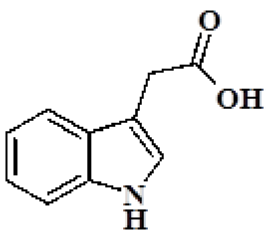
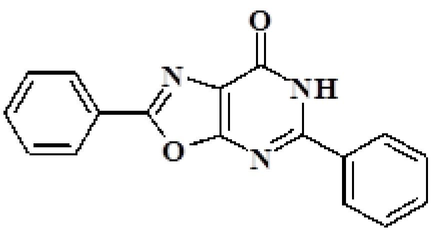
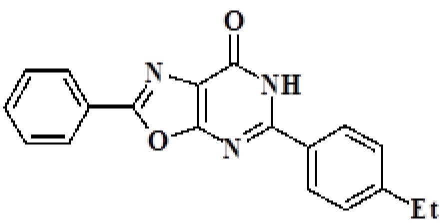
Cucumber (*Cucumis sativus* L.) is an annual dicotyledonous plant belonging to the genus *Cucumis* of the family *Cucurbitaceae*. Cucumber is one of the major vegetable crops having important nutritional, dietary and therapeutic properties, due to which it is widely used in the food and medicinal industry [1-3].The cucumber seed is used as a rich source of biologically active compounds to which belong seed oil (53,7 %) consisting of the main fatty acids such as linoleic acid, oleic acid, palmitic acid, stearic acid; protein (33,8 %) consisting of the essential amino acids such as histidine, threonine, phenylalanine, tyrosine, valine, isoleucine, leucine; carbohydrates (10,3 %); crude fiber (2,0 %); minerals such as Ca, Mg, Na, Mn, Fe, K, Cu, and Zn [4]. Cucumber seed oil has cholesterol-lowering effect due to which it can be used in medicine for the prevention of cardiovascular diseases. The extracts of cucumber leaves, stems, fruits, and seeds are enriched with a broad spectrum of phytonutrients such as β-carotene and α-carotene, zea-xanthin, lutein, vitamins A, C and K, proteins and aminoacids, caffeic acid, glycosides, alkaloids, tannins, phytosterols, terpenoids, saponins, flavonoids, lignans, triterpenes exhibiting antioxidant, anticancer, antidiabetic, antiulcer, antimicrobial, analgesic, hypoglycemic, hypolipidemic, and cytotoxic activity [5-19]. They are applied in the traditional and non-traditional medicine for treatment of cancer, malaria, inflammation, diabetes, hyperlipidemia, and gastric ulcer, infectious, bacterial and fungal diseases. The fresh juice or extract of cucumber fruit are used in dermatology and cosmetics for the manufacture of whitening, moisturizing and anti-aging skin creams and tonics [20]. Today, the plant growth regulators (PGRs), plant biostimulants based on plant growth-promoting rhizobacteria (PGPR) or organic mineral fertilizers, and insecticides are widely used to accelerate cucumber growth and increase yield, and to protect this important agricultural crop from adverse environmental factors, pests and pathogens [21-41]. Nevertheless, the development of new effective environmental safe PGRs to improve cucumber growth and productivity, and enhance tolerance of this important agricultural crop to biotic and abiotic stress-factors is the prominent task for modern agriculture. To innovations in biotechnology for sustainable development of agriculture belongs the elaboration of new PGRs on the basis of low molecular weight synthetic heterocyclic compounds (LMWHC), derivatives of pyridine, pyrimidine, pyrazole, triazine, and oxazole to intensify plant growth and development, and increase crop productivity. As is known LMWHC are widely used in the medicine as drugs for the treatment of bacterial, infectious, viral, fungal, inflammatory, neural, allergic, cancer, and autoimmune diseases [42-55], and in the agriculture as PGRs, herbicides, fungicides, insecticides, acaricides, and antibacterial agents [56-71]. Our numerous works devoted to study of plant growth regulatory activity of LMWHC, synthesized in the Institute of Bioorganic Chemistry and Petrochemistry of NAS of Ukraine, showed that different classes of LMWHC used at very low non-toxic for human health and environment concentrations 10^{-8} M - 10^{-9} M revealed the broad spectrum of biological action on various crops [72-75]. Based on the obtained data, we proposed to use of LMWHC as new effective and ecologically safe substitutes of traditional PGRs in the practice of agricultural biotechnology. The aim of this work was study of the regulatory effect of new LMWHC, derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine and N-sulfonyl substituted of 1,3-oxazole on growth parameters of cucumber (*Cucumis sativus* L.) seedlings, and content of photosynthetic pigments and total soluble protein in the leaves of seedlings.

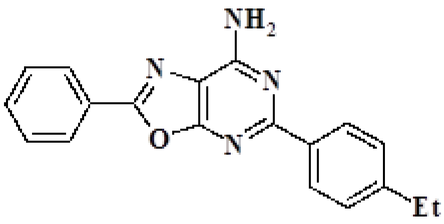
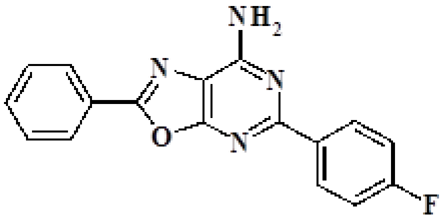
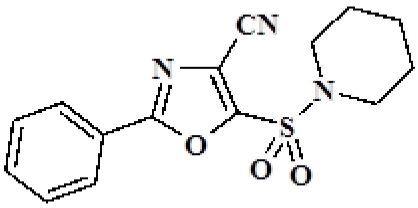
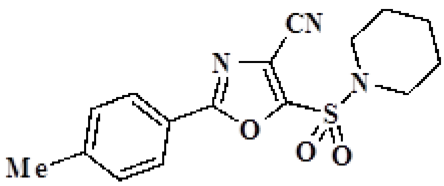
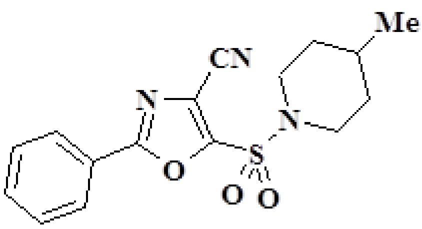
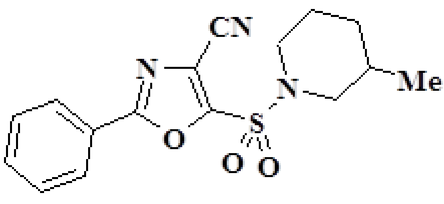
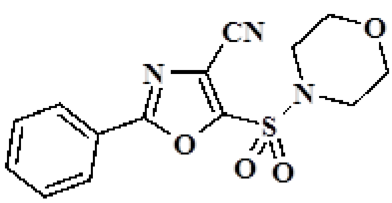
2. MATERIALS AND METHODS

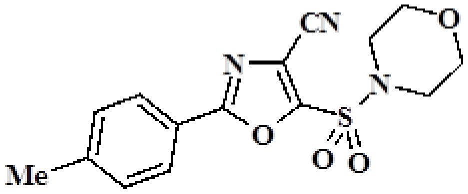
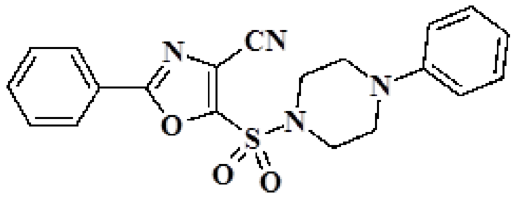
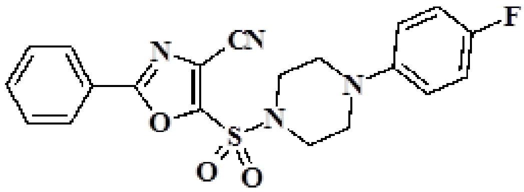
Chemical structure of tested synthetic LMWHC

Our research was devoted to screening of new plant growth regulators based on synthetic LMWHC for intensification of vegetative growth of cucumber. The plant growth regulatory activity of synthetic LMWHC, derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine (compounds **№ 1-4**) and N-sulfonyl substituted of 1,3-oxazole (compounds **№ 5-12**) was studied. The LMWHC were synthesized at the Department for chemistry of bioactive nitrogen-containing heterocyclic compounds of Institute of Bioorganic Chemistry and Petrochemistry of NAS of Ukraine (Table 1). The growth regulatory activity of LMWHC was compared with the activity of plant hormone auxin IAA.

Table 1. The chemical structure of LMWHC used for bioassays

№	**Chemical structure**	**Chemical name and relative molecular weight**
IAA		1*H*-Indol-3-ylacetic acid MW=175.19
1		2,5-Diphenyl[1,3]oxazolo[5,4-*d*]pyrimidin-7(6*H*)-one MW=289.30
2		5-(4-Ethylphenyl)-2-phenyl[1,3]oxazolo[5,4-*d*] pyrimidin-7(6*H*)-one MW=317.35

3		5-(4-Ethylphenyl)-2-phenyl[1,3]oxazolo[5,4-*d*] pyrimidin-7-amine MW=316.37
4		5-(4-Fluorophenyl)-2-phenyl[1,3]oxazolo[5,4-*d*] pyrimidin-7-amine MW=306.30
5		2-Phenyl-5-(1-piperidinylsulfonyl)-1,3-oxazole-4-carbonitrile MW=317.37
6		2-Tolyl-5-(1-piperidinylsulfonyl)-1,3-oxazole-4-carbonitrile MW=331.40
7		5-[(4-Methyl-1-piperidinyl)sulfonyl]-2-phenyl-1,3-oxazole-4-carbonitrile MW=331.40
8		5-[(3-Methyl-1-piperidinyl)sulfonyl]-2-phenyl-1,3-oxazole-4-carbonitrile MW=331.40
9		5-(4-Morpholinylsulfonyl)-2-phenyl-1,3-oxazole-4-carbonitrile MW=319.34

10		2-(4-Methylphenyl)-5-(4-morpholinylsulfonyl)-1,3-oxazole-4-carbonitrile MW=333.37
11		2-Phenyl-5-[(4-phenyl-1-piperazinyl)sulfonyl]-1,3-oxazole-4-carbonitrile MW= 394.46
12		5-{[4-(4-Fluorophenyl)-1-piperazinyl]sulfonyl}-2-phenyl-1,3-oxazole-4-carbonitrile MW= 412.45

Plant growth conditions

In the laboratory conditions we studied impact of phytohormone auxin IAA and synthetic LMWHC, derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine and N-sulfonyl substituted of 1,3-oxazole on germination of seeds and vegetative growth of cucumber (*Cucumis sativus* L.) of cultivar Dzjerelo. With this aim the cucumber seeds were surface sterilized in 1 % $KMnO_4$ solution for 3 min and 96 % ethanol solution for 1 min, and then washed three times with sterile distilled water. After this procedure seeds were placed in the cuvettes (each containing 25-30 seeds) on the perlite moistened with distilled water (control), or with water solution of either derivatives of [1,3]oxazolo [5,4-*d*]pyrimidine, or N-sulfonyl substituted of 1,3-oxazole, or auxin IAA used at the same concentration 10^{-9} M. After this procedure seeds were placed in the thermostat and germinated in the darkness at the temperature 23 °C during 48 h. Sprouted seedlings were placed in the plant growth chamber in which seedlings were grown for 24 days at the 16/8 h light/dark conditions, at the temperature 24 °C, light intensity 3000 lux and air humidity 60-80 %. The comparative analysis of biometric indices of seedlings (i.e. number of germinated seeds (%), length of the over ground part of the seedlings (cm), total number of roots (pcs), total length of roots (mm)) was carried out at the 24th day after their sprouting according to the guideline [76].

Study of impact of LMWHC on content of photosynthetic pigments in the leaves of cucumber

The total content of chlorophyll a, chlorophyll b, and carotenoids was determined in the leaves of 24th-day-old seedlings of cucumber (*Cucumis sativus* L.) of cultivar Dzjerelo grown on the distilled water (control), or on the water solution of either derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine, or N-sulfonyl substituted of 1,3-oxazole, or auxin IAA used at the same concentration 10^{-9}M. The sample (500 mg) of leaves from control and experimental 24th-day-old seedlings of cucumber was homogenized 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) to perform extraction of pigments. The 1 ml of homogenate was centrifuged at 8000 g in a refrigerated centrifuge K24D (MLW, Engelsdorf, Germany) during 5 min and at the temperature 4°C. The obtained precipitate was washed three times with 1 ml 96% etanol 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 total content of chlorophyll a, chlorophyll b, and carotenoids was calculated in accordance with formula [77, 78].

$\mathbf{C_{chl\ a}}$ = 13.36×A664.2 – 5.19×A648.6,

$\mathbf{C_{chl\ b}}$ = 27.43×A648.6 – 8.12A×664.2,

$\mathbf{C_{chl}}$ **(a + b)** = 5.24×A664.2 + 22.24×A648.6,

$\mathbf{C_{car}}$ = (1000×A470 – 2.13×$C_{chl\ a}$ – 97.64×C_{chlb})/209,

Where, $\mathbf{C_{chl}}$ – concentration of chlorophylls (mg/ml),

$\mathbf{C_{car}}$ – concentration of carotenoids (mg/ml),

$\mathbf{C_{chl\ a}}$– concentration of chlorophyll a (mg/ml),

$\mathbf{C_{chl\ b}}$– concentration of chlorophyll b (mg/ml),

A – absorbance value at a proper wavelength in nm.

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

$\mathbf{A_1=(C\times V)/(1000\times a_1)}$

Where, $\mathbf{A_1}$ – content of chlorophyll a or chlorophyll b (mg/g FW),

C - concentration of pigments (mg/ml),

V - volume of extract (ml),

$\mathbf{a_1}$ - sample of plant tissue (g).

Study of impact of LMWHC on content of total soluble protein in in the leaves of cucumber

The determination of total soluble protein content (g of proteins per 100 g of FW of plant material) in the leaves of 24th-day-old seedlings of cucumber (*Cucumis sativus* L.) of cultivar Dzjerelo grown on the distilled water (control), or on the water solution of either derivative of [1,3]oxazolo[5,4-*d*] pyrimidine, or N-sulfonyl substituted of 1,3-oxazole, or auxin IAA used at the same concentration 10^{-9}M was carried out using Bradford protein assay [79]. To prepare plant extracts the sample (100 mg) of leaves of 24th-day-old seedlings of cucumber was homogenized in the porcelain mortar in a 0,1 M sodium phosphate buffer (pH 6,0 – 8,0) at the ratio of 1:5 (weight: volume) at the temperature

4 °C during 1 h. The obtained homogenates were centrifuged at 8000 g in a refrigerated centrifuge K24D (MLW, Engelsdorf, Germany) at the temperature 4 °C during 15 min. Then 1,5 ml of distilled water and 1,5 ml of reagent Coomassie Brilliant Blue G 250 (Bio-Rad, 500-0006) were added to 50 ml of obtained supernatant, and mixture was stirred during 10 min. The optical density of total soluble protein was measured using spectrophotometer Specord M-40 at a wavelength 595 nm. The content of total soluble protein in the sample was determined using the calibration graph constructed on the base of measured OD of the samples containing 1,5 ml solution of bovine serum albumin (BSA) used as a standard and 1,5 ml of reagent the Coomassie Blue G 250 (Bio-Rad, 500-0006). The index of total soluble protein content determined in the leaves of experimental cucumber seedlings was expressed in % according to similar index determined in the leaves of control cucumber seedlings.

Statistical Analysis

Each experiment was performed in triplicate. Statistical analysis of the data was performed using dispersive Student's-t test with the level of significance at $p \leq 0,05$, the values are mean ± Standard Deviation [80].

3. RESULTS AND DISCUSSION

Impact of synthetic LMWHC on growth parameters of cucumber

As is known the major plant hormones auxins and cytokinins are involved in control of plant embryogenesis, seed germination, de-etiolation, cell cycle control, cell elongation and differentiation, protein synthesis, growth and development of plant root and shoot, photosynthesis, development of flower and fruit, prevention of leaf abscission and delaying of leaf senescence [81-87]. In the laboratory conditions we conducted the comparative analysis of regulatory activity of synthetic LMWHC, derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine and N-sulfonyl substituted of 1,3-oxazole, and phytohormone auxin IAA used at the same concentration 10^{-9}M on germination of seeds and growth of 24th-day-old seedlings of cucumber (*Cucumis sativus* L.) of cultivar Dzjerelo (Figure 1). The obtained results showed that some from tested synthetic LMWHC revealed high auxin-like and cytokinin-like stimulating activity on growth of the over ground part of the seedlings of cucumber and improved development of their root system (Figure 1). The comparative statistical analysis of biometric indices of 24th-day-old cucumber seedlings (i.e. number of germinated seeds (%), length of the over ground part of the seedlings (cm), total number of roots (pcs), total length of roots (mm)) showed that the obtained biometric indices of cucumber seedlings grown on the water solution of some from tested synthetic LMWHC, derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine and N-sulfonyl substituted of 1,3-oxazole used at the concentration 10^{-9}M were similar or higher of the biometric indices of cucumber seedlings grown either on the distilled water (control), or on the water solution of auxin IAA used at the same concentration 10^{-9}M (Figure 2).

Figure 1. Impact of synthetic LMWHC, derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine (compounds **№ 1-4**) and N-sulfonyl substituted of 1,3-oxazole (compounds **№ 5-12**), and phytohormone **IAA** – 1*H*-Indol-3-ylacetic acid on growth of 24th-day-old seedlings of cucumber (*Cucumis sativus* L.) of cultivar Dzjerelo as compared to control cucumber seedlings grown on the distilled water (**C**).

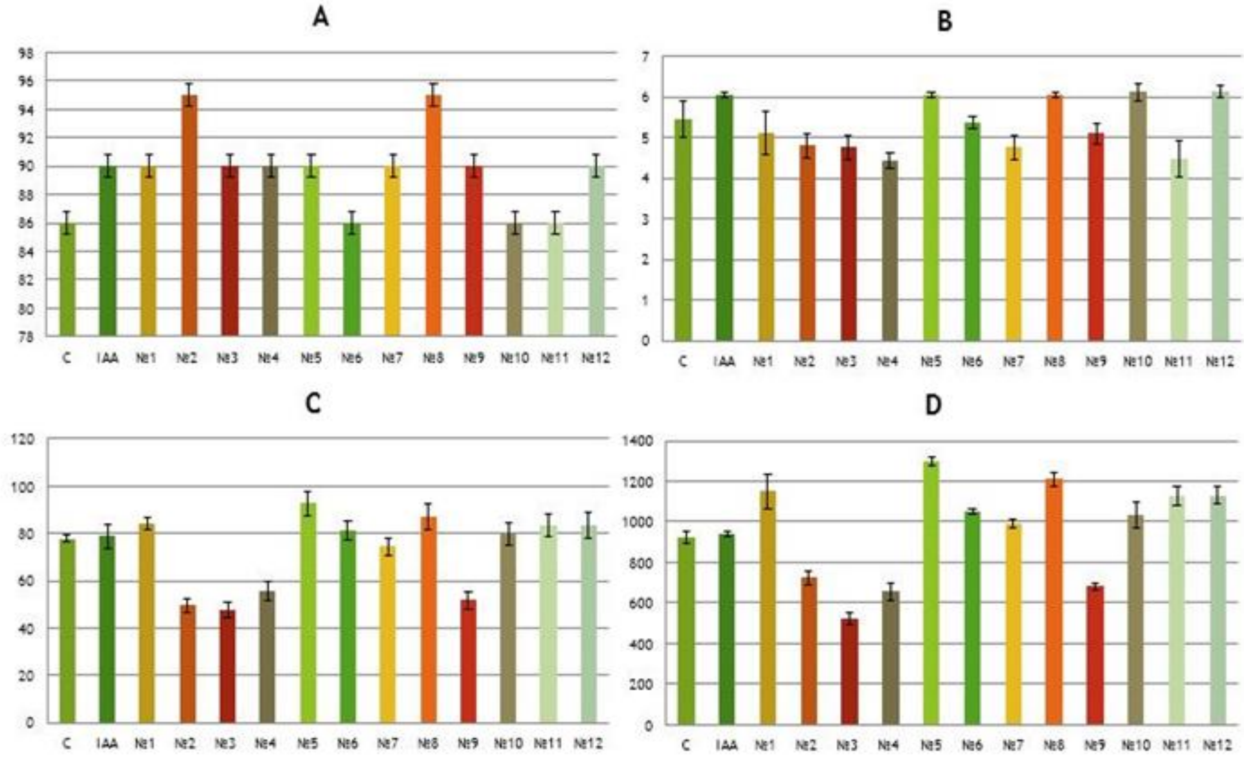


Figure 2. Impact of synthetic LMWHC, derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine (compounds **№ 1-4**) and N-sulfonyl substituted of 1,3-oxazole (compounds **№ 5-12**), and phytohormone **IAA** – 1*H*-Indol-3-ylacetic acid on the biometric indices of 24th-day-old cucumber seedlings (*Cucumis sativus* L.) of cultivar Dzjerelo as compared to control cucumber seedlings grown on the distilled water (**C**). **A** – number of germinated seeds (%), **B** – length of the over ground part of the seedlings (cm), **C** – total number of roots (pcs), **D** – total length of roots (mm).

It was shown that the biometric indices of 24th-day-old cucumber seedlings grown on the water solution of compound **№ 1** used at concentration 10^{-9}M were in average higher of the biometric indices of cucumber seedlings grown either on the distilled water (control), or on the water solution of auxin IAA used at the same concentration 10^{-9}M as follows: according with total number of roots – at the 8,5 % and 7,2 % as compared with control and IAA, respectively; according with total length of roots – at the 24,6 % and 22,6 % as compared with control and IAA, respectively (Figure 2).It was shown that the biometric indices of 24th-day-old cucumber seedlings grown on the water solution of compound **№ 2** used at concentration 10^{-9}M were in average higher of the biometric indices of cucumber seedlings grown either on the distilled water (control), or on the water solution of auxin IAA used at the same concentration 10^{-9}M as follows: according with number of germinated seeds - at the 10,5 % and 5,5 % as compared with control and IAA, respectively (Figure 2).The compounds **№ 3** and **№ 4** stimulated only germination of seeds at the 4,7 % and 4,7 %, accordingly, as compared with control; but they did not showed any stimulating effect on another biometric indices of 24th-day-old cucumber seedlings as compared with control plants (Figure 2). It was shown that the biometric indices of 24th-day-old cucumber seedlings grown on the water solution of compound **№ 5** used at concentration 10^{-9}M were in average higher of the biometric indices of cucumber seedlings grown either on the distilled water (control), or on the water solution of auxin IAA used at the same concentration 10^{-9}M as follows: according with length of seedlings – at the 11 % as compared with control; according with total number of roots – at the 19 % and 18 % as compared with control and IAA, respectively; according with total length of roots – at the 40,7 % and 38 % as compared with control and IAA, respectively (Figure 2).It was shown that the biometric indices of 24th-day-old cucumber seedlings grown on the water solution of compound **№ 6** used at concentration 10^{-9}M were in average higher of the biometric indices of cucumber seedlings grown either on the distilled water (control), or on the water solution of auxin IAA used at the same concentration 10^{-9}M as follows: according with total number of roots – at the 4,7 % and 3,4 % as compared with control and IAA, respectively; according with total length of roots – at the 13,6 % and 11,8 % as compared with control and IAA, respectively (Figure 2). It was shown that the biometric indices of 24th-day-old cucumber seedlings grown on the water solution of compound **№ 7** used at concentration 10^{-9}M were in average higher of the biometric indices of cucumber seedlings grown either on the distilled water (control), or on the water solution of auxin IAA used at the same concentration 10^{-9}M as follows: according with number of germinated seeds - at the 4,7 % as compared with control; according with total length of roots – at the 7,4 % and 5,7 % as compared with control and IAA, respectively (Figure 2). It was shown that the biometric indices of 24th-day-old cucumber seedlings grown on the water solution of compound **№ 8** used at concentration 10^{-9}M were in average higher of the biometric indices of cucumber seedlings grown either on the distilled water (control), or on the water solution of auxin IAA used at the same concentration 10^{-9}M as follows: according with number of germinated seeds – at the 11 % as compared with control; according with length of seedlings – at the 11 % as compared with control; according with total number of roots – at the at the 12 % and 10,6 % as compared with control and IAA, respectively; according with total length of roots – at the 31 % and 29 % as compared with control and IAA, respectively (Figure 2). It was shown that the biometric indices of 24th-day-old cucumber seedlings grown on the water solution of compound **№ 9** used at concentration 10^{-9}M were in average higher of the biometric indices of cucumber seedlings grown on the distilled water (control) as follows: according with number of germinated seeds - at the 4,7 % as compared with control (Figure 2). It was shown that the biometric indices of 24th-day-old cucumber seedlings grown on the water solution of compound **№ 10** used at concentration 10^{-9}M were in average higher of the biometric indices of cucumber seedlings grown on the distilled water (control) as follows: according with length of seedlings – at the 23 % as compared with control; according with total length of roots – at the 11,8 % and 10 % as compared with control and IAA, respectively (Figure 2). It was shown that the biometric indices of 24th-day-old cucumber seedlings grown on the water solution of compound **№ 11** used at concentration 10^{-9}M were in average higher of the biometric indices of cucumber seedlings grown either on the distilled water (control), or on the water solution of auxin IAA used at the same concentration 10^{-9}M as follows: according with total number of roots – at the 7,3 % and 6 % as compared with control and IAA; according with total length of roots – at the 22,6 % and 20,6 % as compared with control and IAA, respectively (Figure 2). It was shown that the biometric indices of 24th-day-old cucumber seedlings grown on the water solution of compound **№ 12** used at concentration 10^{-9}M were in average higher of the biometric indices of cucumber seedlings grown either on the distilled water (control), or on the water solution of auxin IAA used at the same concentration 10^{-9}M as follows: according with number of germinated seeds – at the 12,2 % and 11 % as compared with control and IAA, respectively; according with length of seedlings – at the 23 % as compared with control; according with total number of roots – at the 7,7 % and 6,4 % as compared with control and IAA, respectively; according with total length of roots – at the 22,6 % and 20,6 % as compared with control and IAA, respectively (Figure 2).Thus, the obtained results showed that the highest plant growth regulatory activity revealed synthetic LMWHC, derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine (compound **№ 1**) and N-sulfonyl substituted of 1,3-oxazole (compounds **№ 5, 8, 11, 12**). The high plant growth regulatory activity of compound **№ 1** was expressed in increase in the total number of roots – at the 8,5 % and 7,2 %, and total length of roots – at the 24,6 % and 22,6 % as compared with control and IAA, respectively. Obviously, that the high growth activity of compound **№ 1** can be explained by the presence of the diphenyl substituents at positions 2 and 5, and oxygen at position 7 of oxazolopyrimidine. At the same time, the introduction of the ethylphenyl substituent at position 5 of oxazolopyrimidine (compound **№ 2**), and fluorophenyl or ethylphenyl substituents at position 5 and amino group at position 7 of oxazolopyrimidine (compounds **№ 3** and **4**) leads to inhibitory effect of chemical compounds on plant growth. The plant growth regulatory activity of compound **№ 5** was expressed in increase in the length of seedlings – at the 11 % as compared with control, total number of roots – at the 19 % and 18 %, and total length of roots – at the 40,7 % and 38 % as compared with control and IAA, respectively. Obviously, that the high growth regulatory activity of compound **№ 5** can be explained by the presence of phenyl at position 2 and piperidinylsulfonyl substituents at position 5 of 1,3-oxazole. The high growth regulatory activity of compound **№ 8** can be explained by the presence of phenyl at position 2 and 3-methylpiperidinylsulfonyl substituents at position 5 of 1,3-oxazole. It should be noted that presence of tolyl at the position 2 and piperidinylsulfonyl substituents at position 5 (compound **№ 6**) or phenyl at position 2 and 4-methylpiperidinylsulfonyl substituents at the position 5 (compound **№ 7**) of 1,3-oxazole leads to a decrease in the plant growth regulatory activity**.** Among the compound **№ 11** containing only phenylpiperazine fragment and compound **№ 12** containing 4-fluorophenylpiperazine fragment the higher activity revealed the compound **№ 12.** The plant growth regulatory activity of compound **№ 11** was expressed in increase in the total number of roots – at the 7,3 % and 6 %, and total length of roots – at the 22,6 % and 20,6 % as compared with control and IAA, respectively. The plant growth regulatory activity of compound **№ 12** was expressed in increase in the number of germinated seeds – at the 12,2 % and 11 %, number of roots – at the 7,7 % and 6,4 %, and total length of roots – at the 22,6 % and 20,6 % as compared with control and IAA, respectively.

Impact of synthetic LMWHC on content of photosynthetic pigments in the leaves of cucumber

As is known chlorophylls and carotenoids are the major photosynthetic pigments that play a key role in photosynthesis and photoprotection in plants, provide plant productivity, and have a beneficial effect on human health [77, 78, 88-91]. The plant hormones cytokinins play a key role in the regulation of photosynthetic processes in plant cells [85-87]. In this work, we studied the regulatory effect of synthetic LMWHC, derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine and N-sulfonyl substituted of 1,3-oxazole, and phytohormone auxin IAA on the content of total photosynthetic pigments (chlorophyll a, chlorophyll b, and carotenoids) in the leaves of 24th-day-old seedlings of cucumber (*Cucumis sativus* L.). The obtained results showed that some tested synthetic LMWHC revealed the stimulating cytokinin-like effect on increase in the content of chlorophyll a, chlorophyll b, and carotenoids in the leaves of 24th-day-old cucumber seedlings grown on the water solution of LMWHC used at the concentration 10^{-9}M as compared with the decrease in the content of photosynthetic pigments in the leaves of cucumber seedlings grown either on the distilled water (control), or on the water solution auxin IAA used at similar concentration 10^{-9}M (Figure 3). It was found that among tested LMWHC, derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine the highest regulatory activity revealed the compound **№ 1**, the content of chlorophyll a in the leaves of 24th-day-old cucumber seedlings grown on the water solution of this compound was increased at the 6,9 % as compared with similar indices of control cucumber seedlings grown on the distilled water

(Figure 3).

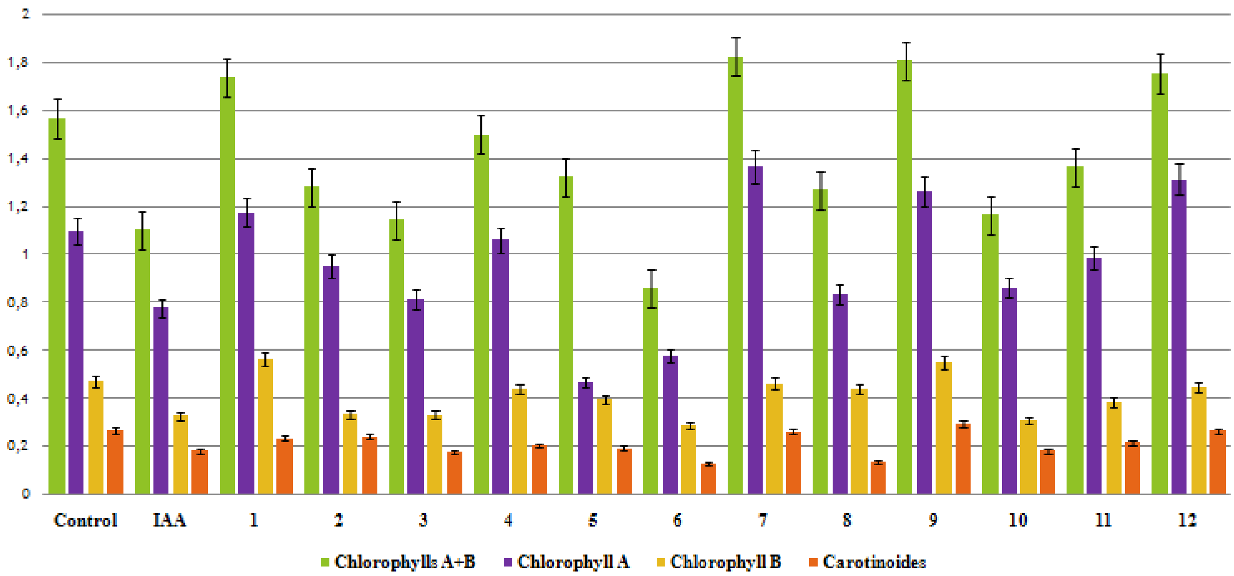


Figure 3. Impact of derivatives of synthetic LMWHC, derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine (compounds **№ 1-4**) and N-sulfonyl substituted of 1,3-oxazole (compounds **№ 5-12**), and phytohormone **IAA** – 1*H*-Indol-3-ylacetic acid on the content of chlorophyll a, chlorophyll b, and carotenoids in the leaves of the 24st-day-old seedlings of cucumber (*Cucumis sativus* L.) of cultivar Dzjerelo as compared to control cucumber seedlings grown on the distilled water.

It was shown that among tested LMWHC, derivatives of N-sulfonyl substituted of 1,3-oxazole the highest regulatory activity revealed the compounds **№ 7, 9** and **12**, the content of chlorophyll a in the leaves of 24th-day-old cucumber seedlings grown on the water solution of these compounds was increased at the 24,3 %, 14,8 % and 19,5 %, accordingly, as compared with similar indices of cucumber seedlings grown on the distilled water (control) (Figure 3). The content of chlorophyll b in the leaves of 24th-day-old cucumber seedlings grown on the water solution of compounds **№ 1** and **7** was also increased at the 20 % and 16,7 %, accordingly, as compared with similar indices of cucumber seedlings grown on the distilled water (control) (Figure 3). The maximum increase in the total content of chlorophyll a+b by an average of 10-16 % was also observed in the leaves of 24th-day-old cucumber seedlings grown on the water solution of compounds **№ 1, 7, 9,** and **12** as compared with similar indices of cucumber seedlings grown on the distilled water (control) (Figure 3). The content of carotenoids was also increased at the 11,7 % in the leaves of 24th-day-old cucumber seedlings grown on the water solution of compound **№ 9** as compared with similar indices of cucumber seedlings grown on the distilled water (control) (Figure 3). Taking into account the obtained results it can be assumed that among derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine the high regulatory activity of compound **№ 1** on increase of content of chlorophylls a and b in the leaves of 24th-day-old cucumber seedlings can be explained by the presence of diphenyl substituents at positions 2 and 5 as compared with lower activity of compounds **№ 2, 3,** and **4** containing fluorophenyl or ethylphenyl substituents at positions 5 of oxazolopyrimidine rings. Among the derivatives of N-sulfonyl substituted of 1,3-oxazole the high regulatory activity of compounds **№ 7, 9** and **12** on increase of content of chlorophylls a and b in the leaves of 24[th]-day-old cucumber seedlings can be explained by the presence of phenyl group at positions 2; and the presence of morpholinylsulfonyl group at positions 5 of oxazole of compound **№ 9** leads to increase its regulatory activity on content of carotenoids in the leaves of 24[th]-day-old cucumber seedlings. The obtained data confirmed the cytokinin-like effect of some synthetic LMWHC, derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine and N-sulfonyl substituted of 1,3-oxazole on activation of photosynthetic processes in the leaves of 24[th]-day-old seedlings of cucumber.

Impact of synthetic LMWHC on content of total soluble protein in the leaves of cucumber

The comparative analysis of regulatory activity of synthetic LMWHC, derivatives of [1,3]oxazolo [5,4-*d*]pyrimidine and N-sulfonyl substituted of 1,3-oxazole, and phytohormone auxin IAA on content of total soluble protein in cucumber seedlings, a key indicator of plant productivity was conducted [1, 29, 30, 92]. As is known, the main role in the control of protein biosynthesis in plant cells belongs to plant hormones auxins and cytokinins [81-87]. It was found that among tested LMWHC, derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine the highest regulatory activity revealed the compounds **№ 2** and **4**, the content of total soluble protein in the leaves of 24[th]-day-old cucumber seedlings grown on the water solution of these compounds was increased by an average of 7-39 % as compared with similar indices of cucumber seedlings grown on the distilled water (control) (Figure 4).

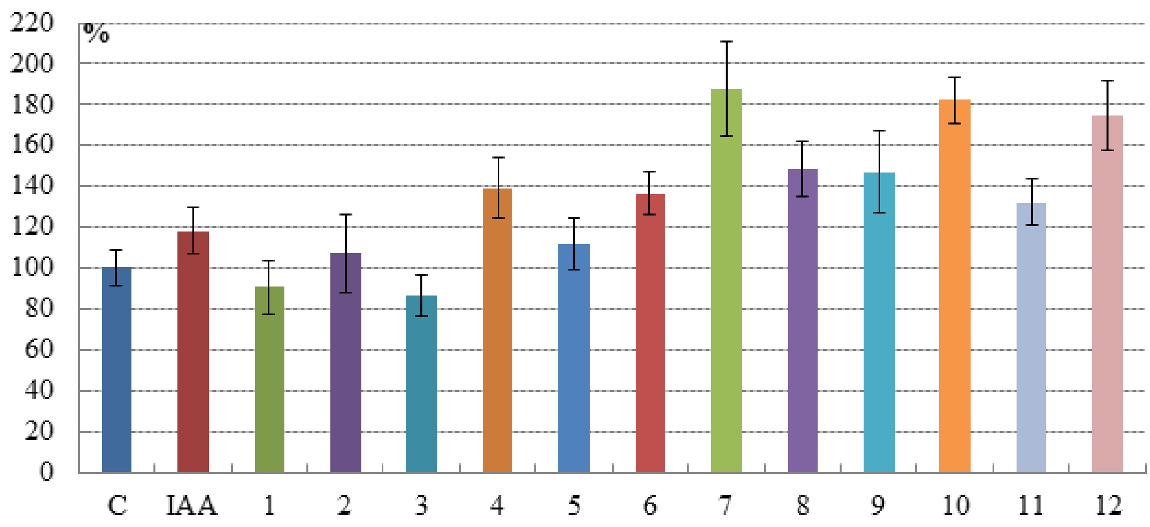


Figure 4. Impact of derivatives of synthetic LMWHC, derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine (compounds **№ 1-4**) and N-sulfonyl substituted of 1,3-oxazole (compounds **№ 5-12**), and phytohormone **IAA** – 1*H*-Indol-3-ylacetic acid on content of total soluble protein (%) in the leaves of seedlings of cucumber (*Cucumis sativus* L.) of cultivar Dzjerelo as compared to similar indices of control cucumber seedlings grown on the distilled water (**C**).

Among tested LMWHC, derivatives of N-sulfonyl substituted of 1,3-oxazole the highest regulatory activity revealed the compounds **№ 7, 10** and **12**, the content of total soluble protein in the leaves of 24th-day-old cucumber seedlings grown on the water solution of these compounds was increased by an average of 74-88 % as compared with similar indices of cucumber seedlings grown on the distilled water (control) (Figure 4). The lower regulatory activity revealed the compounds **№ 6, 8, 9** and **11**, the content of total soluble protein in the leaves of 24th-day-old cucumber seedlings grown on the water solution of these compounds was increased by an average of 36-47 % as compared with similar indices of cucumber seedlings grown on the distilled water (control) (Figure 4). The lowest regulatory activity revealed the compounds **№ 5**, the content of total soluble protein in the leaves of 24th-day-old cucumber seedlings grown on the water solution of these compounds was increased at the 12 % as compared with similar indices of cucumber seedlings grown on the distilled water (control) (Figure 4). Our researches showed also the stimulating effect of phytohormone auxin IAA on the increase at the 18 % of content of total soluble protein in the leaves of cucumber seedlings as compared with similar indices of cucumber seedlings grown on the distilled water (control) (Figure 4). Thus, the obtained data confirmed the auxin- and cytokinin-like effect of some synthetic LMWHC, derivatives of [1,3] oxazolo[5,4-*d*]pyrimidine and N-sulfonyl substituted of 1,3-oxazole on activation of protein biosynthesis in the leaves of 24th-day-old cucumber seedlings.

4. CONCLUSION

Study of plant growth regulatory activity of synthetic LMWHC, derivatives of [1,3]oxazolo [5,4-*d*]pyrimidine and N-sulfonyl substituted of 1,3-oxazole showed that some heterocyclic compounds used at concentration 10^{-9}M revealed the high stimulating effect on the growth of the 24th-day-old seedlings of cucumber (*Cucumis sativus* L.) of cultivar Dzjerelo. Obviously, that the high plant growth regulatory activity of derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine and N-sulfonyl substituted of 1,3-oxazole can be explained by their auxin-like and cytokinin-like stimulating effect on processes of enlargement, proliferation and differentiation of plant cells, intensification of processes of photosynthesis and protein biosynthesis in plant cells leading to formation of plant tissues and organs, and acceleration of plant growth and development [81-87]. The relationship between chemical structure and plant growth regulatory activity of synthetic LMWHC was observed. The obtained results confirmed the possibility of the practical application of synthetic LMWHC, derivatives of [1,3]oxazolo [5,4-*d*]pyrimidine and N-sulfonyl substituted of 1,3-oxazole as new effective regulators of vegetative growth of cucumber plants.

CONFLICT OF INTEREST

Authors stated that there is no conflict of interest.

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