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Acceleration of vegetative growth of wheat (*Triticum aestivum* L.) using [1,3]oxazolo[5,4-*d*]pyrimidine and N-sulfonyl substituted 1,3-oxazole

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Abstract Wheat (*Triticum aestivum* L.) is an important cereal crop cultivated in the most economically developed coutries. The elaboration of new effective growth regulators for intensification of seed germination stage and vegetative growth of wheat is an actual problem for modern agriculture. In our work the comparative analysis of regulating activity of low molecular weight heterocyclic compounds, derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine and N-sulfonyl substituted of 1,3-oxazole, and plant hormones auxins IAA (1*H*-Indol-3-ylacetic acid) and NAA (1-Naphthylacetic acid) on acceleration of vegetative stage of wheat (*Triticum aestivum* L.) cultivar Zimoyarka was conducted. The growth parameters of roots and shoots of the 20^{th}-day-old wheat seedlings grown on the water solution of the chemical heterocyclic compounds used at the concentration 10^{-9}M were similar or higher of the growth parameters of roots and shoots of the wheat seedlings grown on the distilled water (control) or water solution of auxins IAA and NAA used at the same concentration 10^{-9}M. The obtained results confirmed the high auxin-like stimulating effect of derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine and N-sulfonyl substituted of 1,3-oxazole on growth of wheat (*Triticum aestivum* L.) cultivar Zimoyarka during vegetative stage.

Keywords *Triticum aestivum* L., [1,3]oxazolo[5,4-*d*]pyrimidine, N-sulfonyl substituted of 1,3-oxazole, IAA, NAA.

1. Introduction

Wheat (*Triticum aestivum* L.) is the major strategic cereal crop cultivated over the world [1-5]. Wheat provides by 30 % of the food calories consumed by world population (4.5 billion people) [4, 5]. Wheat is used as a raw material for the production of malt and beer [5]. Wheat contains various bioactive compounds such as alkaloids, saponins, glycosides, terpenoids, steroids, flavonoids and tannins that may be used for purposes of pharmaceutical industry [6]. However, despite the rapidly increasing of wheat sowing, there are significant problems with the increasing of the productivity of this crop because world population is expected to reach 9.7 billion people by 2050 [7].

The stress-factors of abiotic and biotic nature negatively affect on vegetative growth of wheat and decrease plant productivity. The plant *g*rowth regulators of natural or synthetic origin and fertilizers are widely used to improve the wheat growth and increase plant productivity [8-14]. Nevertheless, the elaboration of new effective ecologically safe plant growth regulators on the base of low molecular weight heterocyclic compounds is a very strategic approach. As is known, the different classes of low molecular weight heterocyclic compounds, derivatives of pyrimidine, pyrazole, and oxazole are widely applied in the agriculture as plant growth regulators, herbicides, fungicides and antibacterial agents [15-26]. The advantage of using of synthetic heterocyclic compounds is their high effectiveness at very low nanomolar concentrations and environmental safety due to lack of toxic effect on the human, animal and

plant cells; moreover they are widely used in the medical practice as therapeutic agents for treatment of nervous, allergic, gastroesophageal, cancer, bacterial, viral, fungal, infectious, and inflammatory diseases [27-31].

Today the different classes of low molecular weight heterocyclic compounds are synthesized at the Institute of Bioorganic Chemistry and Petrochemistry of National Academy of Sciences of Ukraine. Our previous studies showed that the chemical compounds belonging to derivatives of pyridine, pyrimidine, pyrazole and isoflavones revealed the high stimulating effect on germination of seeds and growth of the various agricultural crops during vegetative stage [32-37]. Therefore, the great theoretical and practical interest is application of the chemical heterocyclic compounds to intensify the vegetative growth of wheat.

This work is devoted to the study of the comparative effect of chemical low molecular weight heterocyclic compounds, derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine and N-sulfonyl substituted of 1,3-oxazole and plant hormones auxins IAA (1*H*-Indol-3-ylacetic acid) and NAA (1-Naphthylacetic acid) on acceleration of vegetative stage of wheat (*Triticum aestivum* L.) cultivar Zimoyarka.

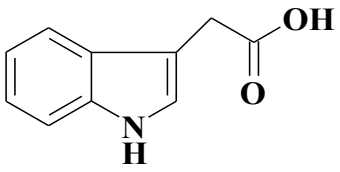
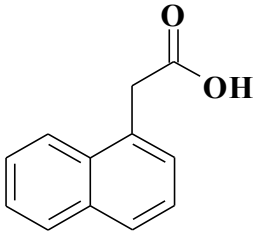
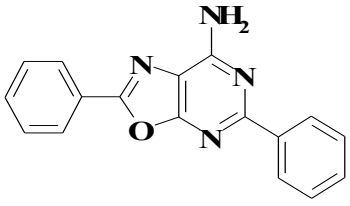
2. Materials and methods

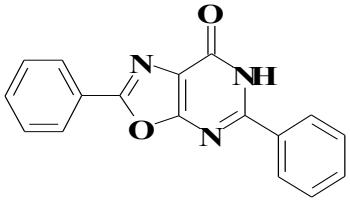
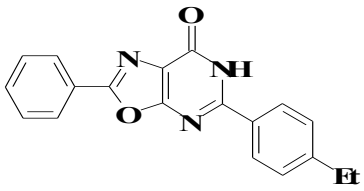
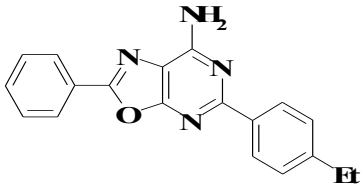
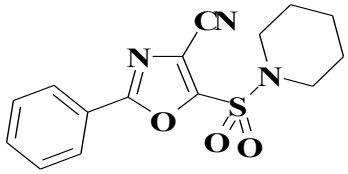
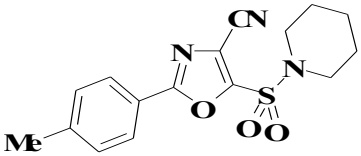
2.1. Chemical structure of heterocyclic compounds and plant hormones used for bioassays

The comparative analysis of the plant growth regulating activity of [1,3]oxazolo[5,4-*d*]pyrimidine (compounds 1 - 4) and N-sulfonyl substituted of 1,3-oxazole (compounds 5 and 6) derivates, and plant phytohormones auxins IAA (1*H*-Indol-3-ylacetic acid) and NAA (1-Naphthylacetic acid) was conducted.

The chemical structure, chemical name and molecular mass (MM) of the tested compounds and plant hormones auxins IAA (1*H*-Indol-3-ylacetic acid) and NAA (1-Naphthylacetic acid) are shown in the Table 1.

Table 1: Chemical structure of plant hormones IAA and NAA and chemical heterocyclic compounds

№	Chemical structure of compounds	Chemical name and relative molecular mass of compounds
IAA		IAA (1*H*-Indol-3-ylacetic acid), MM 175.19
NAA		NAA (1-Naphthylacetic acid), MM 186.21
1		7-Amino-2,5-diphenyl[1,3]oxazolo[5,4-*d*]pyrimidine, MM 288.31

2		2,5-Diphenyl[1,3]oxazolo[5,4-*d*]pyrimidin-7(6*H*)-one, MM 289.30
3		5-(4-Ethylphenyl)-2-phenyl[1,3]oxazolo[5,4-*d*]pyrimidin-7(6*H*)-one, MM 317.35
4		7-Amino-5-(4-ethylphenyl)-2-phenyl[1,3]oxazolo[5,4-*d*]pyrimidine, MM 316.37
5		2-Phenyl-5-(piperidin-1-ylsulfonyl)-1,3-oxazole-4-carbonitrile, MM 317.37
6		2-Tolyl-5-(piperidin-1-ylsulfonyl)-1,3-oxazole-4-carbonitrile, MM 331.40

2.2. Plant treatment and growing conditions

The seeds of wheat (*Triticum aestivum* L.) cultivar Zimoyarka were surface sterilized by 1 % $KMnO_4$ solution for 3 min followed by treatment with 96 % ethanol solution for 1 min, and then washed three times with sterile distilled water. After this procedure wheat seeds were placed in the cuvettes (each containing 20-25 seeds) on the perlite moistened with distilled water (control), or with the solution of chemical heterocyclic compounds, derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine and N-sulfonyl substituted of 1,3-oxazole used at the concentration 10^{-9}M or with the solution of plant hormones auxins IAA and NAA used at the same concentration 10^{-9}M. Afterward, the control and experimental wheat seeds were placed in the thermostat for their germination in the darkness at the temperature 25 °C during 48 hours. Sprouted wheat seedlings were placed in the growth chamber where seedlings were grown for 20 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 the growth parameters of the wheat seedlings (i.e. number of germinated seeds (%), length of shoots (cm), total number of roots (pcs), total length of roots (mm)) was carried out on the 20 day after their sprouting according to the guideline [38].

2.3. Statistical Analysis

All experiments were performed in three replicates. 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 ± SD [39].

3. Results

3.1. Effect of chemical heterocyclic compounds and auxins on wheat vegetative growth

In the laboratory conditions we studied the regulatory effect of the chemical heterocyclic compounds, derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine and N-sulfonyl substituted of 1,3-oxazole, and plant hormones auxins IAA and NAA on germination of seeds and growth of root and shoot system of the wheat (*Triticum aestivum* L.) seedlings cultivar Zimoyarka. It was shown that all tested compounds and auxins IAA and NAA used at the concentration of 10^{-9}M revealed the high stimulating effect on growth of root and shoot system of the wheat seedlings during 20 days (Fig. 1).

A

B

Figure 1: Effect of chemical heterocyclic compounds, derivatives of [1,3]oxazolo[5,4-d]pyrimidine (№1 - 7-amino-2,5-diphenyl[1,3]oxazolo[5,4-d]pyrimidine, №2 - 2,5-diphenyl[1,3]oxazolo[5,4-d]pyrimidin-7(6H)-one, №3 - 5-(4-ethylphenyl)-2-phenyl[1,3]oxazolo[5,4-d]pyrimidin-7(6H)-one, №4 - 7-amino-5-(4-ethylphenyl)-2-phenyl[1,3]oxazolo[5,4-d]pyrimidine), compounds derivatives of N-sulfonyl substituted of 1,3-oxazole (№5 - 2-phenyl-5-(piperidin-1-ylsulfonyl)-1,3-oxazole-4-carbonitrile and №6 - 2-tolyl-5-(piperidin-1-ylsulfonyl)-1,3-oxazole-4-carbonitrile), and plant hormones auxins IAA and NAA on growth of shoot system of the 20th-day-old

wheat seedlings as compared to control (C) wheat seedlings (A); and growth of root system of the 20th-day-old wheat seedlings as compared to control (C) wheat seedlings (B)

Obviously, the high auxin-like growth stimulating effects of the chemical compounds is explained by their impact on plant cell elongation, proliferation and differentiation that are the basic processes of plant growth and development [40-45].

The comparative analysis of the biometric indexes (i.e. number of germinated seeds (%), length of shoots (cm), total number of roots (pcs), total length of roots (mm)) showed that the biometric indexes of the 20th-day-old wheat seedlings grown on the 10^{-9}M water solution of the chemical heterocyclic compounds were similar or higher of the biometric indexes of wheat seedlings grown on the 10^{-9} M water solution of auxins IAA and NAA as compared with lower biometric indexes of wheat seedlings grown on the distilled water (control).

The results of stimulating effect of the heterocyclic compounds on the biometric indexes of the 20th-day-old wheat seedlings are shown on the Fig 2.

It was found that the biometric indexes of the 20th-day-old wheat seedlings grown on the 10^{-9}M water solution of compound **№1** were higher of the biometric indexes of wheat seedlings grown either on the distilled water (control) or on the 10^{-9}M water solution of auxins IAA and NAA in average: according to length of shoots – at the 17% as compared with control; according to total length of roots – at the 32 % as compared with control; according to total number of roots – at the 85%, 51% and 20% as compared with control, IAA and NAA, respectively (Fig. 2).

The biometric indexes of the 20th-day-old wheat seedlings grown on the 10^{-9}M water solution of the compound **№2** were higher of the biometric indexes of wheat seedlings grown either on the distilled water (control) or on the 10^{-9} M water solution of auxins IAA and NAA in average: according to length of shoots – at the 13% as compared with control; according to total length of roots – at the 89%, 45% and 34% as compared with control, IAA and NAA, respectively; according to total number of roots – at the 30% as compared with control (Fig. 2).

The biometric indexes of the 20th-day-old wheat seedlings grown on the 10^{-9}M water solution of compound **№3** were higher of the biometric indexes of wheat seedlings grown either on the distilled water (control) or on the 10^{-9}M water solution of auxins IAA and NAA in average: according to length of shoots – at the 20%, 6% and 8% as compared with control, IAA and NAA, respectively; according to total length of roots – at the 57%, 21% and 11% as compared with control, IAA and NAA, respectively; according to total number of roots – at the 57%, 24% and 16% as compared with control, IAA and NAA, respectively (Fig. 2).

The biometric indexes of the 20th-day-old wheat seedlings grown on the 10^{-9}M water solution of compound **№4** were higher of the biometric indexes of wheat seedlings grown either on the distilled water (control) or on the 10^{-9}M water solution of auxins IAA and NAA in average: according to length of shoots – at the 16% as compared with control; according to total length of roots – at the 66%, 27% and 17% as compared with control, IAA and NAA; according to total number of roots – at the 65%, 31% and 23% as compared with control, IAA and NAA, respectively (Fig. 2).

The biometric indexes of the 20th-day-old wheat seedlings grown on the 10^{-9} M water solution of compound **№5** were higher of the biometric indexes of wheat seedlings grown either on the distilled water (control) or on the 10^{-9}M water solution of auxin IAA in average: according to length of shoots – at the 13% as compared with control; according to total length of roots – at the 41% and 8% as compared with control and IAA, respectively; according to total number of roots – at the 53 % as compared with control (Fig. 2).

The biometric indexes of the 20th-day-old wheat seedlings grown on the 10^{-9}M water solution of compound **№6** were higher of the biometric indexes of wheat seedlings grown on the distilled water (control) in average: according to length of shoots – at the 10% as compared with control; according to total length of roots – at the 36 % as compared with control; according to total number of roots – at the 10% as compared with control (Fig. 2).

Thus, the comparative analysis of biometric indexes of the 20th-day-old wheat seedlings grown on the 10^{-9}M water solution of heterocyclic compounds showed that the highest growth stimulating activity from tested compounds the derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine revealed the compound **№3** - 5-(4-ethylphenyl)-2-phenyl[1,3]oxazolo[5,4-*d*]pyrimidin-7(6*H*)-one and compound **№4** - 7-amino-5-(4-ethylphenyl)-2-phenyl[1,3]oxazolo[5,4-*d*]pyrimidine. The obtained results may be explained by the presence of different

substituents at the 7th position of pyrimidine fragment: oxygen - in the compound **№3** or amino group - in the compound **№4**, respectively.

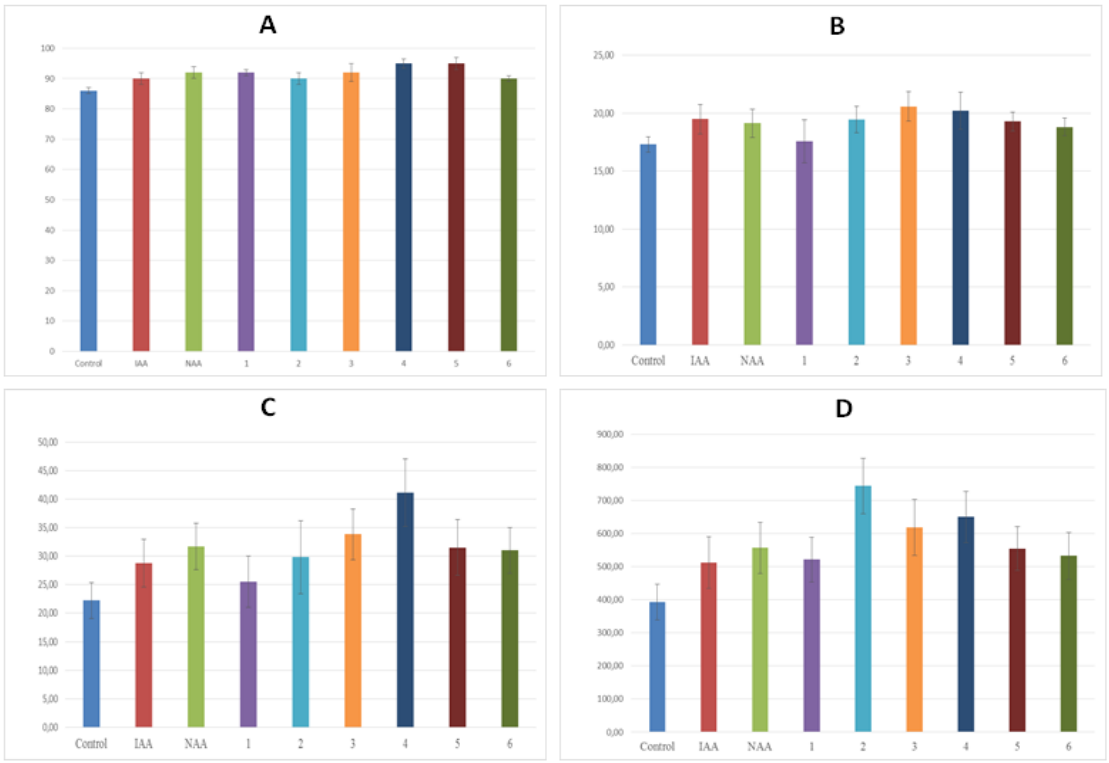


Figure 2: Effect of chemical heterocyclic compounds derivatives of [1,3]oxazolo[5,4-d]pyrimidine (№1 - 7-amino-2,5-diphenyl[1,3]oxazolo[5,4-d]pyrimidine, №2 - 2,5-diphenyl[1,3]oxazolo[5,4-d]pyrimidin-7(6H)-one, №3 - 5-(4-ethylphenyl)-2-phenyl[1,3]oxazolo[5,4-d]pyrimidin-7(6H)-one, №4 - 7-amino-5-(4-ethylphenyl)-2-phenyl[1,3]oxazolo[5,4-d]pyrimidine), compounds derivatives of N-sulfonyl substituted of 1,3-oxazole (№5 - 2-phenyl-5-(piperidin-1-ylsulfonyl)-1,3-oxazole-4-carbonitrile and №6 - 2-tolyl-5-(piperidin-1-ylsulfonyl)-1,3-oxazole-4-carbonitrile), and plant hormones auxins IAA and NAA on the biometric indexes of the 20th-day-old wheat seedlings. A – number of germinated seeds (%), B – length of wheat shoots (cm), C – total number of roots (pcs), D – total length of roots (mm)

At the same time the compound **№1** - 7-amino-2,5-diphenyl[1,3]oxazolo[5,4-*d*]pyrimidine and compound **№2** - 2,5-diphenyl[1,3]oxazolo[5,4-*d*]pyrimidin-7(6*H*)-one that contain phenyl substituent at the 5th position and amino group at the 7th position of pyrimidine fragment revealed lower growth stimulating activity on growth of the wheat seedlings.

Our experiments showed also that the minor stimulating activity on growth of wheat seedlings demonstrated the derivatives of N-sulfonyl substituted of 1,3-oxazoles: compound **№5** - 2-phenyl-5-(piperidin-1-ylsulfonyl)-1,3-oxazole-4-carbonitrile and compound **№6 –** 2- tolyl-5-(piperidin-1-ylsulfonyl)-1,3-oxazole-4-carbonitrile, their activity was not significantly differed between these compounds, therefore correlation between chemical structure and biological activity has not been found at these compounds.

4. Discussion

Today the numerous works are devoted to study the impact of plant growth regulators of synthetic or natural origin, organic and mineral fertilizers on improving of growth and increase of productivity of wheat [8-14]. The new promising approach is the elaboration of new effective growth regulators on the base of low molecular weight heterocyclic compounds as effective environmental safe substitutes of phytohormones and traditional plant growth regulators for acceleration of wheat growth and improving quality of production. The numerous literature data

witness about widespread application in the agricultural practice of different classes of low molecular weight heterocyclic compounds derivatives of pyridine, pyrimidine, pyrazole, triazine, and oxazole, as a new effective plant growth regulators, herbicides, fungicides and antibacterial agents [15-26].

Our previous researches confirmed the possibility of application of low molecular weight heterocyclic compounds the derivatives of pyridine, pyrimidine, pyrazole, and oxazole to increase the effectivity of shoot organogenesis of flax under *in vitro* conditions and to accelerate the vegetative growth of various agricultural crops such as maize, pea, pumpkin, cucumber, tomato, and rape [32-37]. Taking into account the results of our previous researches and literature data the great theoretical and practical interest is study the possibility of using of low molecular weight heterocyclic compounds for intensification of vegetative growth of wheat.

The results obtained in the present work indicate that low molecular weight heterocyclic compounds the derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine and N-sulfonyl substituted of 1,3-oxazoles used at the concentration 10^{-9}M demonstrated high auxin-like stimulating effect on the growth of wheat seedlings during 20 days.

It was found that the growth stimulating activity of these compounds was varied depending on different substituents in the chemical structure of heterocyclic compounds. The comparative analysis of the stimulating activity of heterocyclic compounds derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine and N-sulfonyl substituted of 1,3-oxazoles on the growth of wheat (*Triticum aestivum* L.) of cultivar Zimoyarka indicate that the highest activity revealed the compound **№3** - 5-(4-ethylphenyl)-2-phenyl[1,3]oxazolo[5,4-*d*]pyrimidin-7(6*H*)-one, which contains oxygen at the 7^{th} position of pyrimidine fragment and compound **№4** - 7-amino-5-(4-ethylphenyl)-2-phenyl[1,3]oxazolo[5,4-*d*]pyrimidine, which contains amino group at the 7^{th} position of pyrimidine fragment of oxazole. Obviously, that growth stimulating activity of compounds derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine may be depended from substituents at the 5^{th} and 7^{th} positions of pyrimidine fragment.

5. Conclusion

The regulatory activity of chemical low molecular weight heterocyclic compounds derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine and N-sulfonyl substituted of 1,3-oxazoles on vegetative growth of wheat (*Triticum aestivum* L.) cultivar Zimoyarka was studied. It was shown that the heterocyclic compounds used at the concentration 10^{-9}M demonstrated the auxin-like growth regulatory activity, which was similar or higher of the activity of plant hormones auxins IAA and NAA. The obtained biometric indexes of the 20^{th}-day-old wheat seedlings grown on the 10^{-9}M water solution of heterocyclic compound were as generally higher of the biometric indexes of wheat seedlings grown either on the distilled water (control) or on the 10^{-9}M water solution of auxins IAA and NAA. The growth regulatory activity of the heterocyclic compounds was varied depending on different substituents in the chemical structure of heterocyclic compounds. The obtained results confirmed the possibility of practical application of chemical heterocyclic compounds the derivatives of [1,3]oxazolo[5,4-*d*]pyrimidine and N-sulfonyl substituted of 1,3-oxazoles as new effective regulators of vegetative growth of wheat (*Triticum aestivum* L.) of cultivar Zimoyarka.

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