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Stimulating effect of five and six-membered heterocyclic compounds on seed germination and vegetative growth of maize (*Zea mays* L.)

Victoria Tsygankova, Yaroslav Andrusevich, Olexandra Shtompel, Artem Hurenko, Roman Solomyannyj, Galyna Mrug, Mikhaylo Frasinyuk, Volodymyr Brovarets

Department for Chemistry of Bioactive Nitrogen-Containing Heterocyclic Compounds, Institute of Bioorganic Chemistry and Petrochemistry, National Academy of Sciences of Ukraine, 1, Murmanskaya str., 02660, Kyiv, Ukraine

Abstract

Maize (*Zea mays* L.) is an important crop for world agriculture. The elaboration of new effective growth regulators for intensification of maize growth and improvement of product quality is very actual problem. In this work impact of synthetic five and six-membered heterocyclic compounds derivatives of pyrimidine, pyrazole, isoflavones and phytohormones auxins IAA and NAA on germination of seeds and vegetative growth of maize was studied. Obtained data showed that treatment of maize seeds by heterocyclic compounds and auxins IAA and NAA used in concentrations ranging from 10^{-5}M to 10^{-13}M in water solution resulted in intensification of seed germination and increase of growth parameters of maize seedlings as compared to lower growth parameters of control untreated seedlings. Comparative statistical analysis showed that the biometric indexes of two-week maize seedlings grown on the water solution of heterocyclic compounds used in concentrations ranging from 10^{-9}M - 10^{-10}M in water solution were as generally higher or similar to biometric indexes of maize seedlings grown on the water solution of auxins IAA and NAA used in the same concentrations as compared to lower biometric indexes of control maize seedlings grown on the distilled water (control). It was found that the highest growth stimulating activity showed compounds derivatives of isoflavones and pyrimidine, whereas derivatives of pyrazole showed lower stimulating activity. Obtained results indicate perspective of application of low molecular weight heterocyclic compounds derivatives of pyrimidine, pyrazole and isoflavones as new effective stimulators of seed germination and growth of maize seedlings.

Keywords: *Zea mays* L., auxins IAA and NAA, heterocyclic compounds, pyrimidine, pyrazole and isoflavones

1. Introduction

Global climate change and environmental pollution by anthropogenic factors negatively effect on growth and development of agricultural crops, resulting in decrease their productivity and resistance to diseases caused by pathogens and pests, as well as to highly toxic for human and animal health herbicides and pesticides that are ubiquitously used for crop protection [1-11]. In world practice of biotechnology for creation of new varieties of crops with genetically improved commercially important characteristics (i.e. improved crop productivity and enhanced adaptive properties to adverse environmental factors) the different tools based on traditional and modern molecular plant breeding (which includes various research areas: conventional plant breeding, pure line selection, mass selection, hybrid breeding, pedigree breeding, population breeding, ideotype breeding, plant mutation breeding, marker-assisted selection, mapping genes of interest, high-throughput phenotyping and genomic selection, etc.) [12-22], plant tissue culture and micropropagation [23-26], genetic engineering and GM crops are widely used [27-30]. Together with these tools the most promising is the approach based on using of phytohormones and plant growth regulators of synthetic origin and biostimulants of natural origin for regulation of genetic program of plant growth and development to increase of crop productivity and resistance to abiotic and biotic stress-factors (such as cold, drought, salinity and soil pollution by anthropogenic factors and various pathogens and pests) [31-38].

Maize or corn (*Zea mays* L.) belongs to cereal and oilseed crops cultivated in the different world countries [39, 40]. Maize is widely used as source of nutrients such as proteins, carbohydrates, lipids, vitamins, dietary fiber and oil for food industry [41- 46], as source of biological active compounds for the cosmetic and pharmaceutical industry [46-50] as well as the raw material for the biofuel industry and animal feed [51-56].

The problem of increasing of maize grain yield and its quality, ecological plasticity and resistance of maize plants to stressful environmental factors, as well as to different types of pathogens and pests is quite relevant [57-62]. In the world agricultural practice the technologies of intensive cultivation of maize using plant growth regulatory substances of natural and synthetic origin as well as fertilizers and herbicides are widely applied [63-72].

The great theoretical and practical interest is the elaboration of new effective ecologically safe plant growth regulators created on the base of low molecular weight heterocyclic compounds for improving of maize growth and increase its productivity. Today the different classes of low molecular weight heterocyclic compounds of synthetic or natural origin are widely used in the medical practice as potential therapeutic agents for treatment of viral, bacterial, fungal, infectious, cancer, gastroesophageal, nervous, inflammatory and allergic diseases and in the agricultural practice as stimulators of plant growth, herbicides, insecticides, fungicides, and antimicrobial agents [73-86]. The advantage of application of these heterocyclic compounds is based on their high physiological effect at very low concentrations, broad specificity of action on different agricultural crops and lack of toxicity for plant, animal and human health.

At the Institute of Bioorganic Chemistry and Petrochemistry of National Academy of Sciences of Ukraine during the last years the new ecologically safe biostimulants of natural origin were created [38, 87- 91] and nowadays screening of new plant growth substances elaborated on the base of low molecular weight five and six-membered heterocyclic compounds is carried out [92]. Numerous researches confirm that the most of these compounds reveal high biological activity on animal and human cells and may be used as perspective medical drugs for treatment of immune, cancer, viral, infectious, nervous, and cardiovascular and other diseases [93-99].

Our previous experiments conducted on the isolated tissue cultures of *Linum usitatissimum* L. cultivar heavenly showed that some low molecular weight heterocyclic compounds derivatives of pyridine, pyrimidine, pyrazole and isoflavones considerably stimulate plant shoot organogenesis *in vitro* conditions [92]. Considering literature data and results of our previous researches the great interest is study the possibility of application of chemical low molecular weight five and six-membered heterocyclic compounds for intensification of growth and development of maize.

The objective of this work is study impact of chemical low molecular weight five and six-membered heterocyclic compounds derivatives of pyrimidine, pyrazole and isoflavones on germination of seeds and vegetative growth of maize (*Zea mays* L.).

2. Materials and Methods

2.1. Chemical structure of tested compounds

In our experiments we tested plant growth regulating activity of low molecular weight five and six-membered heterocyclic compounds derivatives of pyrimidine (6-Methanesulfonyl-imidazo[1,2-*a*]pyrimidine-5-ylamine, 1-Benzyl-5-methanesulfonyl-3-phenyl-1*H*-pyrimidine-2,4-dione, 4-Benzylamino-5-*p*-tolyl-5*H*-pyrrolo-[3,2-*d*]pyrimidin-7-yl)-phosphonic acid diethyl ester), pyrazole (Ethyl 2-(4-oxo-7-methyl-4,7-dihydro-3*H*-pyrazolo[3,4-*d*][1,2,3]triazin-3-yl)-acetate, 5-Hydrazino-1-phenyl-1*H*-pyrazole-4-carbo hydrazide, 3-Ethyl-7-methyl-3,7-dihydro-4*H*-pyrazolo[3,4-*d*][1,2,3]triazin-4-one) and isoflavones (5-Hydroxy-7-methoxy-6-(methoxymethyl)-2-phenyl-4*H*-chromen-4-one, 5-Hydroxy-7-methoxy-8-(methoxymethyl)-3-(4-methoxy phenyl)-4*H*-chromen-4-one, 5-Hydroxy-7-methoxy-6-(methoxymethyl)-3-(2-methoxyphenyl)-4*H*-chromen-4-one), synthesized at the Department for Chemistry of Bioactive Nitrogen-Containing Heterocyclic Compounds of Institute of Bioorganic Chemistry and Petrochemistry of NAS of Ukraine [100-103]. Plant growth regulating activity of chemical heterocyclic compounds was compared with activity of plant growth regulators which belong to the phytohormones auxins of natural origin IAA (Indole-3-acetic acid) or synthetic origin NAA (1-Naphthaleneacetic acid).

Chemical structures of phytohormones auxins and heterocyclic compounds used for bioassays are shown on the Fig. 1.

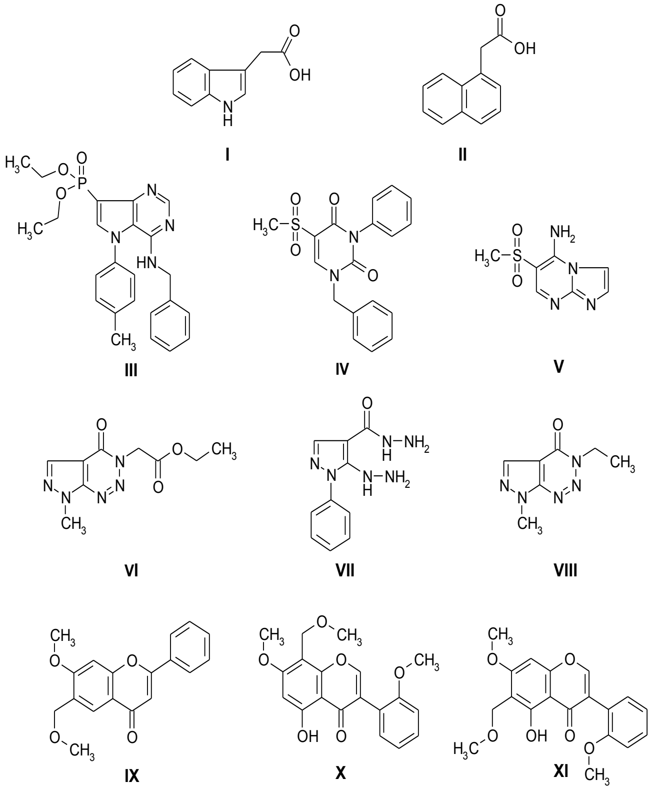


Fig 1: Chemical structures of synthetic compounds used for bioassays

I. IAA (Indole-3-acetic acid), Molar mass=175.19 g/mol
II. NAA (1-Naphthaleneacetic acid), Molar mass=186.21 g/mol
III. Compound 4-Benzylamino-5-*p*-tolyl-5*H*-pyrrolo-[3,2-*d*]pyrimidin-7-yl)-phosphonic acid diethyl ester, Molar mass=450.48 g/mol
IV. Compound 1-Benzyl-5-methanesulfonyl-3-phenyl-1*H*-pyrimidine-2,4-dione, Molar mass=356.48 g/mol
V. Compound 6-Methanesulfonyl-imidazo[1,2-*a*]pyrimidine-5-ylamine, Molar mass=212.23 g/mol
VI. Compound 7-Methyl-4-oxo-4,7-dihydropyrazolo[3,4-*d*][1,2,3]triazin-3-yl)-acetic acid ethyl ester, Molar mass= 237.22 g/mol
VII. Compound 5-Hydrazino-1-phenyl-1*H*-pyrazole-4-carbohydrazide, Molar mass=232.25 g/mol
VIII. Compound 3-Ethyl-7-methyl-3,7-dihydro-4*H*-pyrazolo[3,4-*d*][1,2,3]triazin-4-one, Molar mass= 179.18 g/mol
IX. Compound 5-Hydroxy-7-methoxy-6-(methoxymethyl)-2-phenyl-4*H*-chromen-4-one, Molar mass= 312.32 g/mol
X. Compound 5-Hydroxy-7-methoxy-8-(methoxymethyl)-3-(4-methoxyphenyl)-4*H*-chromen-4-one, Molar mass= 342.35 g/mol
XI. Compound 5-Hydroxy-7-methoxy-6-(methoxymethyl)-3-(2-methoxyphenyl)-4*H*-chromen-4-one, Molar mass= 342.35g/mol

2.2. Plant Growing and Treatment

In the laboratory conditions we studied impact of synthetic heterocyclic compounds on germination of seeds and growth of seedlings of maize (*Zea mays* L.) cultivar Odesskaya 10. With this aim seeds were surface sterilized successively in 1

% KMnO4 solution for 3 min and 96% ethanol solution for 1 min and then washed three times in sterilized distilled water. After this procedure seeds were placed in the cuvettes (each containing 20-25 seeds) on the perlite moistened with distilled water (control) or with water solution of each heterocyclic compound or auxins IAA or NAA (experiment), each compound was tested in concentrations ranging from 10^{-5}M - 10^{-13}M/1 of distilled water. Control and experimental seeds were placed in the thermostat for their germination in darkness at the temperature 23^0 C during the 3 days. Sprouted seedlings were placed in the plant growth chamber in which seedlings were grown for two weeks at the 16/8 h light/dark conditions, at the temperature 22–24 ^{0}C, light intensity 3000 lux and air humidity 60-80 %**.** Comparative analysis of biometric indexes of seedlings (i.e. number of germinated seeds (%), seedlings height (cm), roots number (pcs), roots length (mm)) was carried out at the 14th day after their sprouting according to the guideline [104].

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 $P<0.05$, the values are mean ± SD [105].

3. Results

3.1. Stimulating effect of chemical heterocyclic compounds and auxins IAA and NAA on germination of seeds and growth of maize seedlings

Impact of chemical heterocyclic compounds derivatives of pyrimidine (6-Methanesulfonyl-imidazo[1,2-*a*]pyrimidine-5-ylamine, 1-Benzyl-5-methanesulfonyl-3-phenyl-1*H*-pyrimidine-2,4-dione, 4-Benzylamino-5-*p*-tolyl-5*H*-pyrrolo-[3,2-*d*]pyrimidin-7-yl)-phosphonic acid diethyl ester), pyrazole (7-Methyl-4-oxo-4,7-dihydropyrazolo[3,4-*d*][1,2,3] triazin-3-yl)-acetic acid ethyl ester, 5-Hydrazino-1-phenyl-1*H*-pyrazole-4-carbohydrazide, 3-Ethyl-7-methyl-3,7-dihydro-4*H*-pyrazolo[3,4-*d*][1,2,3]triazin-4-one) and isoflavones (5-Hydroxy-7-methoxy-6-(methoxymethyl)-2-phenyl-4*H*-chromen-4-one, 5-Hydroxy-7-methoxy-8-(methoxymethyl)-3-(4-methoxyphenyl)-4*H*-chromen-4-one, 5-Hydroxy-7-methoxy-6-(methoxymethyl)-3-(2-methoxy phenyl)-4*H*-chromen-4-one) on the growth and development of maize seedlings in the laboratory conditions is shown on the Fig.2-4.

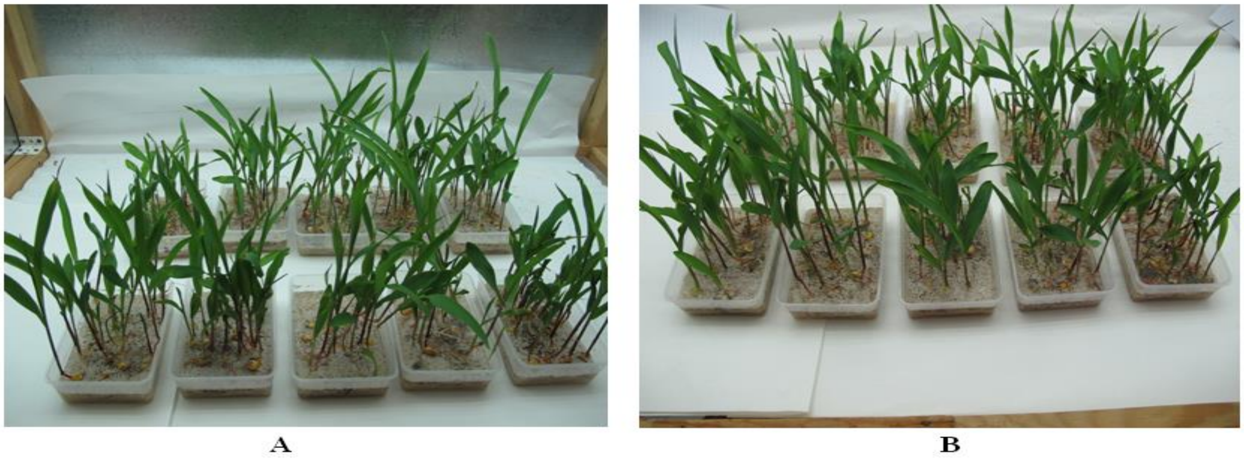
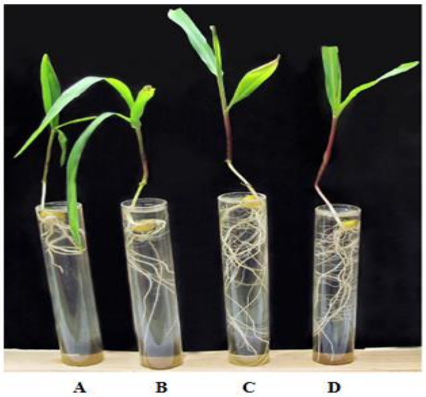
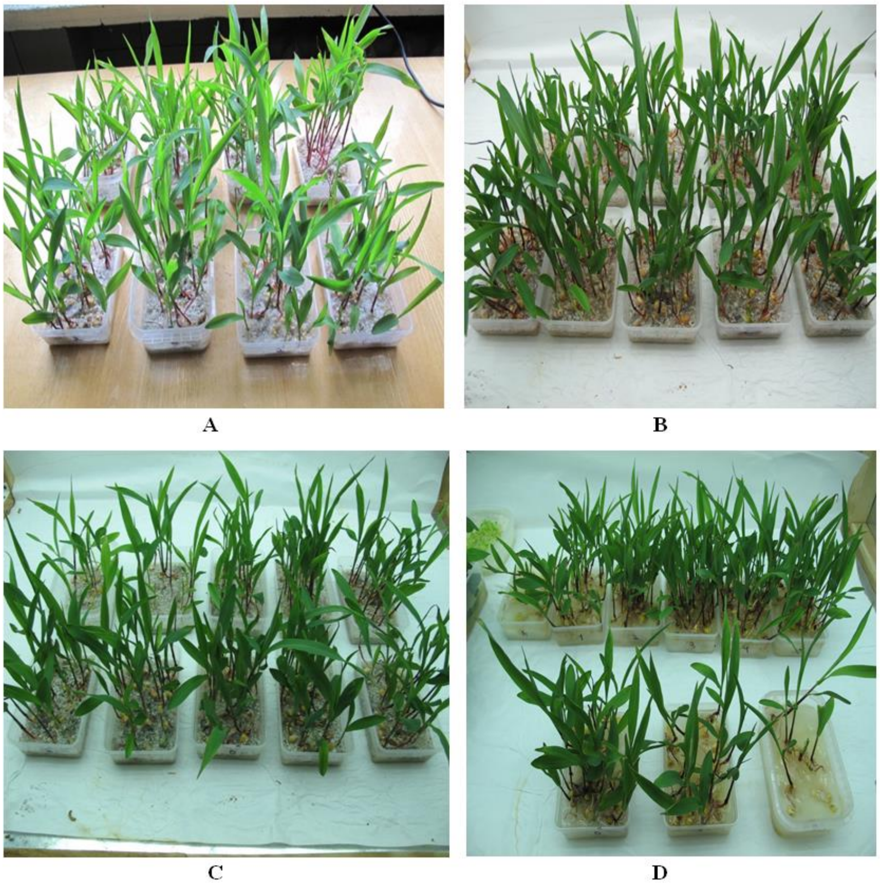


Fig 2: Impact of chemical heterocyclic compounds derivatives of isoflavones used at the concentrations ranging from 10^{-5}M - 10^{-13}M in water solution (from the second top left cuvette to the last right bottom cuvette) on the growth and development of 14th-day-old maize seedlings as compared to control maize seedlings grown on the distilled water (the first top left cuvette)
A – Compound 5-Hydroxy-7-methoxy-6-(methoxymethyl)-2-phenyl-4*H*-chromen-4-one. **B –** Compound 5-Hydroxy-7-methoxy-8-(methoxymethyl)-3-(4-methoxyphenyl)-4*H*-chromen-4-one



- **A-** Control (distilled water)
- **B-** Compound 5-Hydroxy-7-methoxy-6-(methoxymethyl)-2-phenyl-4*H*-chromen-4-one.
- **C-** Compound 5-Hydroxy-7-methoxy-6-(methoxymethyl)-3-(2-methoxyphenyl)-4*H*-chromen-4-one
- **D-** Compound 5-Hydroxy-7-methoxy-8-(methoxymethyl)-3-(4-methoxyphenyl)-4*H*-chromen-4-one

Fig 3: Impact of chemical heterocyclic compounds derivatives of isoflavones used at the concentrations 10^{-8}M in water solution on the formation of roots at 14th-day-old maize seedlings



A- Compound 7-Methyl-4-oxo-4,7-dihydropyrazolo[3,4-*d*][1,2,3]triazin-3-yl)-acetic acid ethyl ester

B- Compound 5-Hydrazino-1-phenyl-1*H*-pyrazole-4-carbohydrazide

C- Compound 3-Ethyl-7-methyl-3,7-dihydro-4*H*-pyrazolo[3,4-*d*][1,2,3]triazin-4-one

D- Compound 6-Methanesulfonyl-imidazo[1,2-*a*]pyrimidine-5-ylamine

Fig 4: Impact of chemical heterocyclic compounds derivatives of pyrazole and pyrimidine used at the concentrations ranging from 10^{-5}M - 10^{-13}M in water solution (from the second top left cuvette to the last right bottom cuvette) on the growth and development of 14th-day-old maize seedlings as compared to control maize seedlings grown on the distilled water (the first top left cuvette)

It was found that all tested heterocyclic compounds used in concentrations ranging from 10^{-5}M - 10^{-13}M in water solution significantly accelerate of maize seed germination, plant growth and development of the root system as compared to control plants.

At the same time according with maize seedlings growth parameters the activity of phytohormones auxins of natural origin IAA and synthetic origin NAA used at the same concentrations ranging from 10^{-5}M - 10^{-11}M/l of distilled water was similar or lower than activity of heterocyclic compounds as compared to control (Fig. 5).

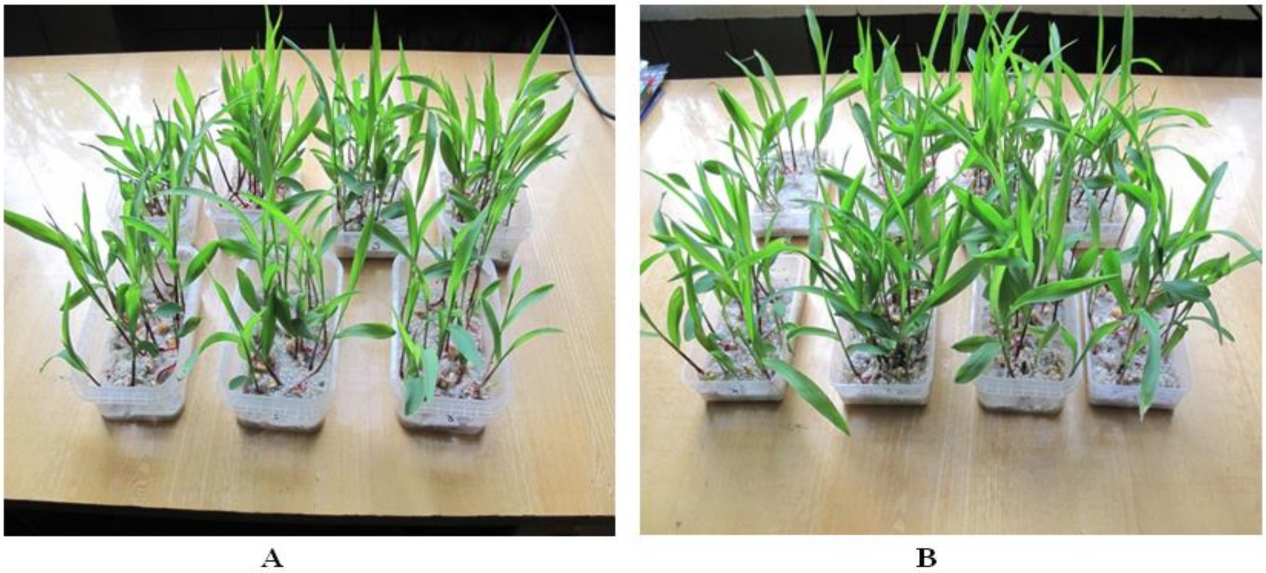


Fig 5: Impact of phytohormones auxins IAA and NAA used at the concentrations ranging from 10^{-5}M - 10^{-11}M in water solution (from the second top left cuvette to the last right bottom cuvette) on the growth and development of 14th-day-old maize seedlings as compared to control maize seedlings grown on the distilled water (the first top left cuvette). **A -** IAA (Indole-3-acetic acid) **B –** NAA (1-Naphthaleneacetic acid)

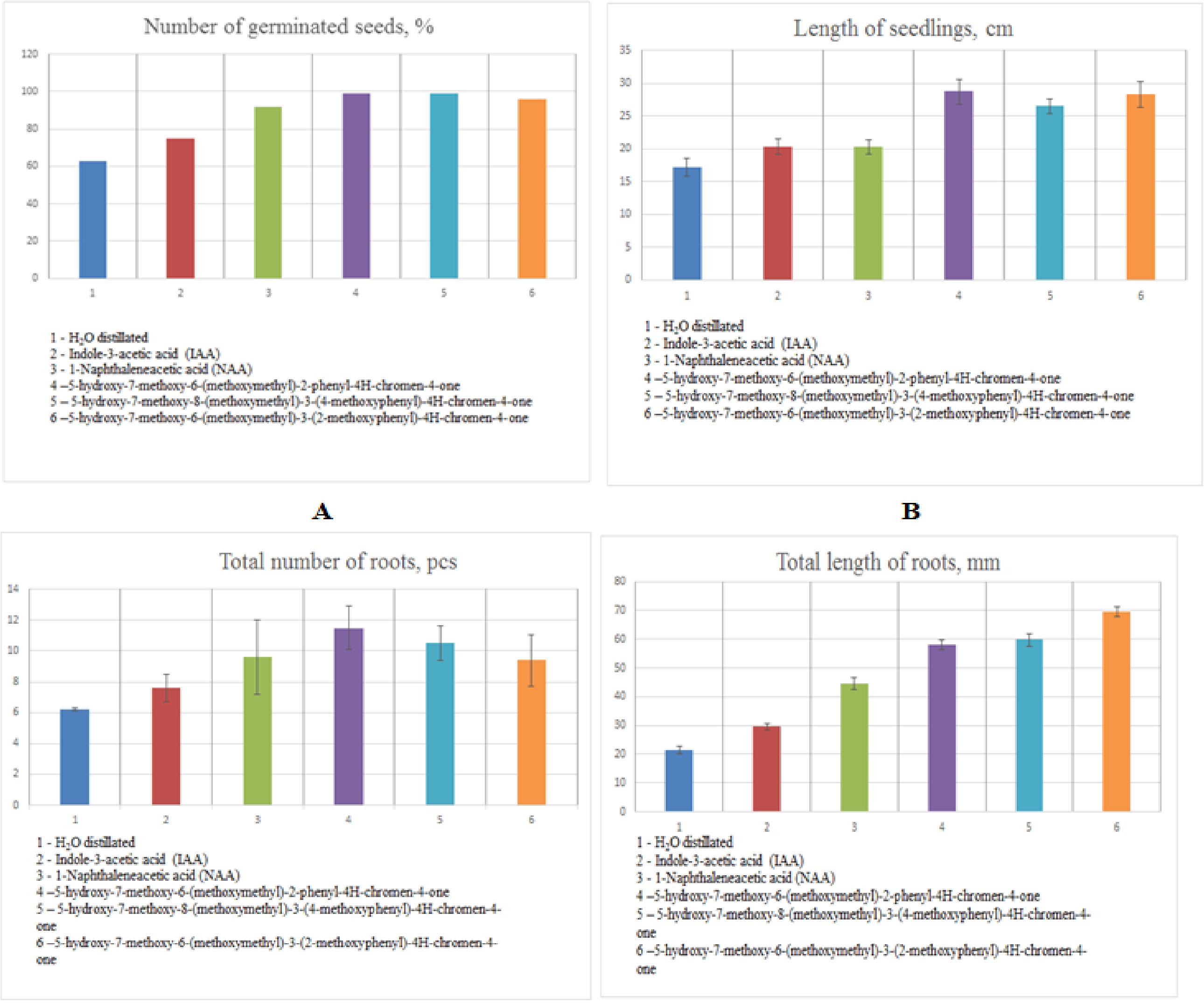
It was shown that the optimal physiologically active concentrations at which heterocyclic compounds revealed the highest growth stimulating activity were 10^{-9}M - 10^{-10}M/l of distilled water as compared to control.

3.2. Comparative statistical analysis of biometric indexes of maize seedlings grown on the water solution of heterocyclic compounds and auxins IAA and NAA

Comparative statistical analysis of biometric indexes of maize seedlings (i.e. number of germinated seeds (%), length of seedlings (cm), total number of roots (pcs), total length of roots (mm)) showed that the biometric indexes of experimental maize seedlings grown on the water solutions of heterocyclic compounds derivatives of isoflavones and pyrazole used at the concentration 10^{-9}M in water solution, as well as pyrimidine used at the concentration 10^{-10}M in water solution were as generally higher or similar to biometric indexes of maize seedlings grown on the water solution of natural auxin IAA and synthetic auxin NAA used at the concentrations ranging from 10^{-9}M - 10^{-10}M in water solution as compared with lower biometric indexes of control maize seedlings grown on the distilled water.

Our experiments showed that according to average indexes of maize seedlings the highest growth stimulating activity from all tested heterocyclic compounds revealed compounds derivatives of isoflavones (Fig. 6) and pyrimidine (Fig. 7), at the same time derivatives of pyrazole (Fig. 8) showed lower stimulating activity.

Particularly, the biometric indexes of two-week maize seedlings grown on the 10^{-9}M water solution of 5-Hydroxy-7-methoxy-6-(methoxymethyl)-2-phenyl-4*H*-chromen-4-one were as generally higher than the biometric indexes of maize seedlings grown either on the distilled water (control) or on the 10^{-9}M water solution of auxins IAA or NAA as follows: according with index of seed germination - at the 57%, 32% and 8% as compared with control, IAA and NAA respectively; according with length of seedlings – at the 67%, 41% and 41% as compared with control, IAA and NAA respectively; according with total length of roots – at the 2,7 times as compared with control and at the 96% and 30% as compared with IAA and NAA respectively; according with total number of roots – at the 85%, 51% and 20% as compared with control, IAA and NAA respectively (Fig. 6).



A **B**

C **D**

Fig 6: Impact of chemical heterocyclic compounds derivatives of isoflavones and phytohormones auxins IAA and NAA used at the concentration 10^{-9}M in water solution on biometric indexes of 14th-day-old maize seedlings

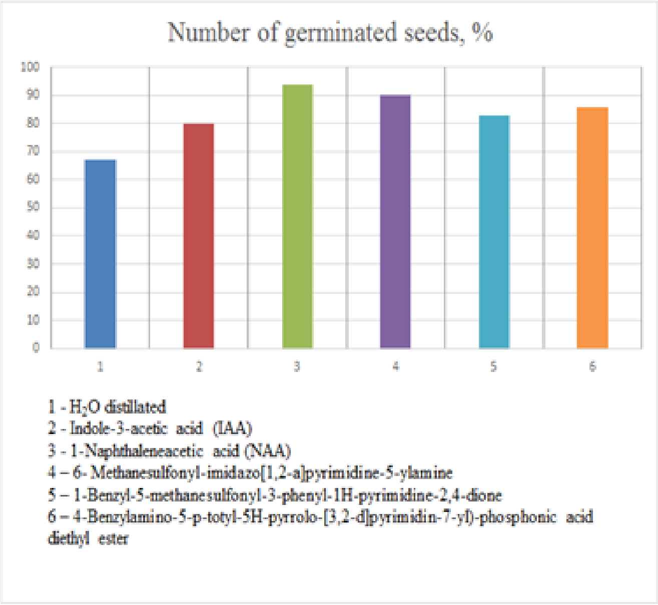
A – Number of germinated seeds (%). **B** – Length of seedlings (cm). **C** – Total number of roots (pcs). **D** – Total length of roots (mm).

The biometric indexes of two-week maize seedlings grown on the 10^{-9}M water solution of 5-Hydroxy-7-methoxy-8-(methoxymethyl)-3-(4-methoxyphenyl)-4*H*-chromen-4-one were as generally higher than the biometric indexes of maize seedlings grown either on the distilled water (control) or on the 10^{-9} M water solution of auxins IAA or NAA as follows: according with index of seed germination - at the 57%, 32% and 8% as compared with control, IAA and NAA respectively; according with length of seedlings – at the 54%, 30% and 31% as compared with control, IAA and NAA respectively; according with total length of roots – at the 2,8 times as compared with control and at the 102% and 34% as compared with IAA and NAA respectively; according with total number of roots – at the 69%, 38% and 9% as compared with control, IAA and NAA respectively (Fig. 6).

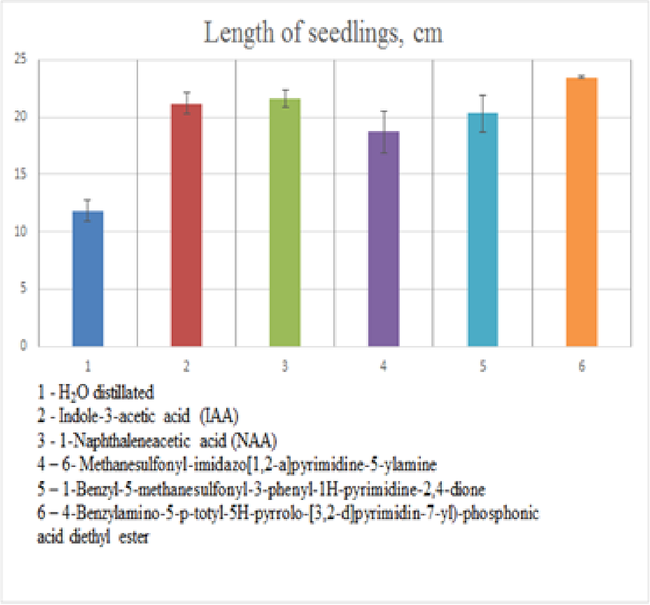
The biometric indexes of two-week maize seedlings grown on the 10^{-9}M water solution of 5-Hydroxy-7-methoxy-6-(methoxymethyl)-3-(2-methoxyphenyl)-4*H*-chromen-4-one were as generally higher than the biometric indexes of maize seedlings grown either on the distilled water (control) or on the 10^{-9} M water solution of auxins IAA or NAA as follows: according with index of seed germination - at the 52%, 28% and 4% as compared with control, IAA and NAA respectively; according with length of seedlings – at the 65%, 39% and 39% as compared with control, IAA and NAA respectively; according with total length of roots – at the 3,3 times as compared with control and at the 136% and 56% as compared with IAA and NAA respectively; according with total number of roots – at the 52% and 24% as compared with control and IAA respectively (Fig. 6).

It was found that the biometric indexes of two-week maize seedlings grown on the 10^{-10}M water solution of 6-Methanesulfonyl-imidazo[1,2-*a*]pyrimidine-5-ylamine, were as generally higher than the biometric indexes of maize seedlings grown either on the distilled water (control) or on the 10^{-10}M water solution of auxins IAA or NAA as follows: according with index of seed germination - at the 34% and 13% as compared with control and IAA respectively; according with length of seedlings – at the 59% as compared with control; according with total length of roots – at the 5,1 times as compared with control and at the 71% and 29% as compared with IAA and NAA respectively; according with total number of roots – at the 2,8 times as compared with control and at the 8% and 24% as compared with IAA and NAA respectively (Fig. 7).

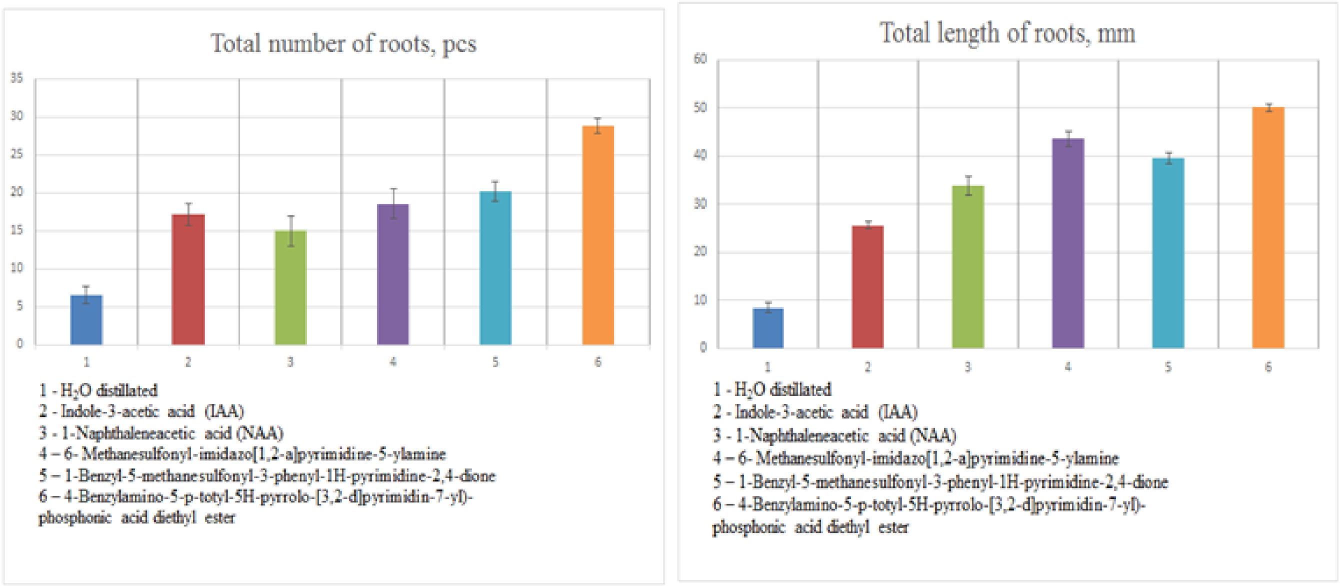
The biometric indexes of two-week maize seedlings grown on the 10^{-10}M water solution of 1-Benzyl-5-methanesulfonyl-3-phenyl-1*H*-pyrimidine-2,4-dione were as generally higher than the biometric indexes of maize seedlings grown either on the distilled water (control) or on the 10^{-10}M water solution of auxins IAA or NAA as follows: according with index of seed germination - at the 24% and 4% as compared with control and IAA respectively; according with length of seedlings – at the 72% as compared with control; according with total length of roots – at the 4,7 times as compared with control and at the 55% and 17% as compared with IAA and NAA respectively; according with total number of roots – at the 2,8 times as compared with control and at the 17% and 35% as compared with IAA and NAA respectively (Fig. 7).



A



B



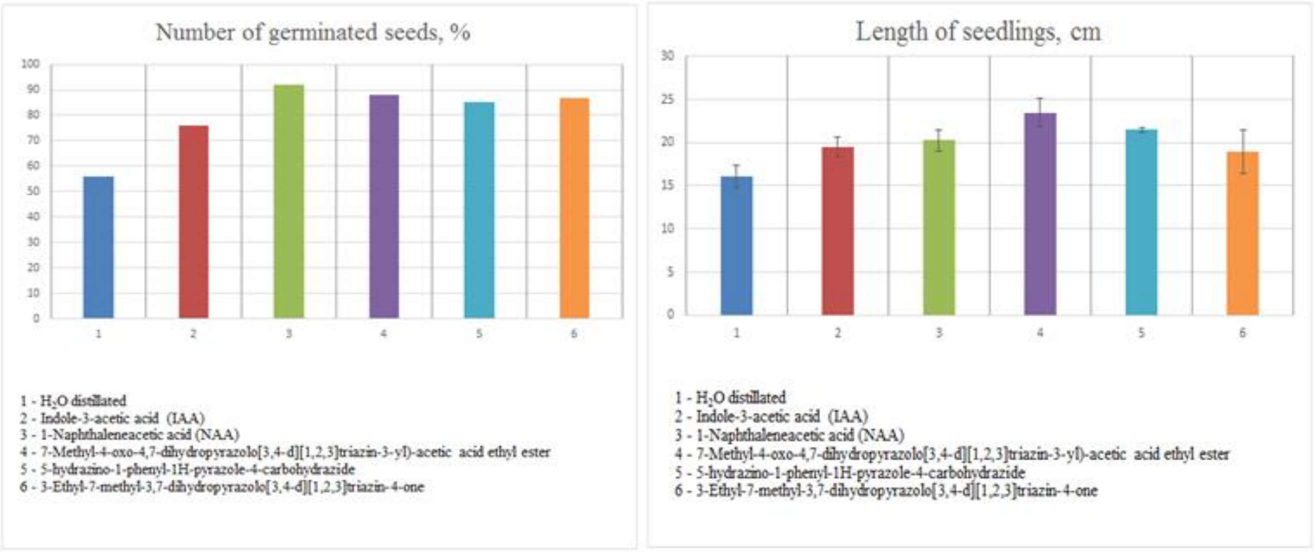
C **D**

Fig 7: Impact of chemical heterocyclic compounds derivatives of pyrimidine and phytohormones auxins IAA and NAA used at the concentration 10^{-10}M in water solution on biometric indexes of 14th-day-old maize seedlings

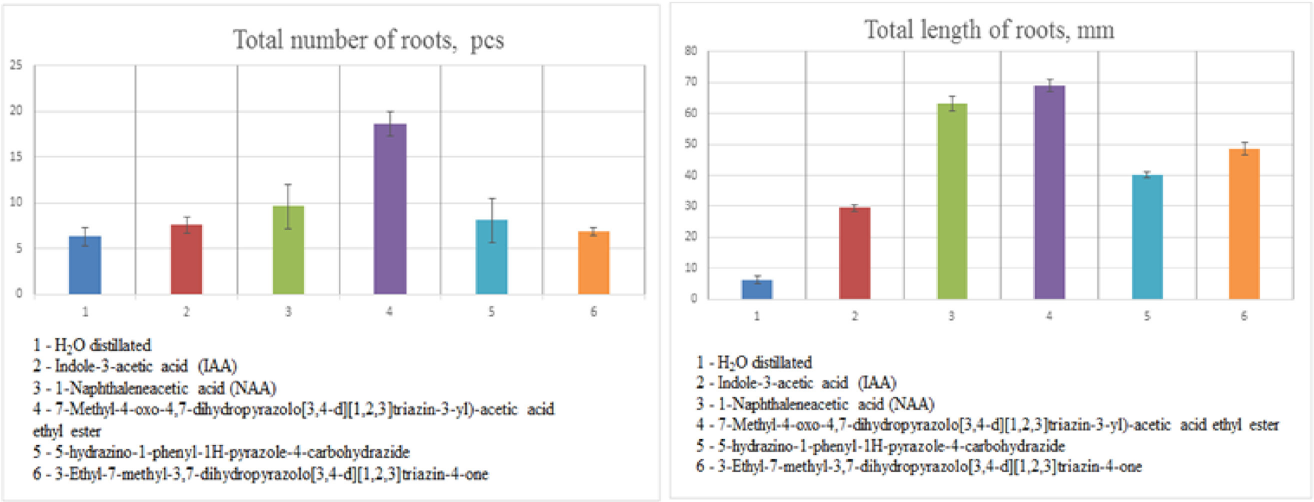
A – number of germinated seeds (%), **B –** Length of seedlings (cm), **C –** Total number of roots (pcs), **D –** Total length of roots (mm)

The biometric indexes of two-week maize seedlings grown on the 10^{-10}M water solution of 4-Benzylamino-5-*p*-tolyl-5*H*-pyrrolo-[3,2-*d*]pyrimidin-7-yl)-phosphonic acid diethyl ester were as generally higher than the biometric indexes of maize seedlings grown either on the distilled water (control) or on the 10^{-10}M water solution of auxins IAA or NAA as follows: according with index of seed germination - at the 28% and 8% as compared with control and IAA respectively; according with length of seedlings – at the 99%, 11% and 9% as compared with control, IAA and NAA respectively; according with total length of roots – at the 6,1 times as compared with control and at the 96% and 49% as compared with IAA and NAA respectively; according with total number of roots – at the 4,4 times as compared with control and at the 67% and 92% as compared with IAA and NAA respectively (Fig. 7).

It was found that the biometric indexes of two-week maize seedlings grown on the 10^{-9}M water solution of 7-Methyl-4-oxo-4,7-dihydropyrazolo[3,4-*d*][1,2,3]triazin-3-yl)-acetic acid ethyl ester were as generally higher than the biometric indexes of maize seedlings grown either on the distilled water (control) or on the 10^{-9} M water solution of auxins IAA or NAA as follows: according with index of seed germination - at the 57% and 16% as compared with control and IAA respectively; according with length of seedlings – at the 46%, 21% and 18% as compared with control, IAA and NAA respectively; according with total length of roots – at the 11 times as compared with control and at the 134% and 9% as compared with IAA and NAA respectively; according with total number of roots – at the 195 %, 145% and 94% as compared with control, IAA and NAA respectively (Fig. 8).



A **B**



C **D**

Fig 8: Impact of chemical heterocyclic compounds derivatives of pyrazole and phytohormones auxins IAA and NAA used at the concentration 10^{-9}M in water solution on biometric indexes of 14th-day-old maize seedlings
A – Number of germinated seeds (%), **B –** Length of seedlings (cm), **C –** Total number of roots (pcs), **D –** Total length of roots (mm)

It was found that the biometric indexes of two-week maize seedlings grown on the 10^{-9}M water solution of 5-Hydrazino-1-phenyl-1*H*-pyrazole-4-carbohydrazide were as generally higher than the biometric indexes of maize seedlings grown either on the distilled water (control) or on the 10^{-9} M water solution of auxins IAA or NAA as follows: according with index of seed germination - at the 52% and 12% as compared with control and IAA respectively; according with length of seedlings – at the 34%, 10% and 6% as compared with control, IAA and NAA respectively; according with total length of roots – at the 6,4 times as compared with control and at the 36% as compared with IAA respectively; according with total number of roots – at the 29% and 7% as compared with control and IAA respectively (Fig. 8).

It was found that the biometric indexes of two-week maize seedlings grown on the 10^{-9}M water solution of 3-Ethyl-7-methyl-3,7-dihydro-4*H*-pyrazolo[3,4-*d*][1,2,3]triazin-4-one were as generally higher than the biometric indexes of maize seedlings grown either on the distilled water (control) or on the 10^{-9} M water solution of auxins IAA or NAA as follows: according with index of seed germination - at the 55% and 15% as compared with control and IAA respectively; according with length of seedlings – at the 17% as compared with control; according with total length of roots – at the 7,3 times as compared with control and at the 65% as compared with IAA respectively; according with total number of roots – at the 10% as compared with control (Fig. 8).

Obtained results demonstrated that all tested compounds revealed high stimulating effect (which as generally was similar or higher than the effect of the phytohormones IAA and NAA) on the growth and development of maize seedlings during the first two weeks of plant growth.

4. Discussion

The elaboration of new effective technologies for intensification of plant growth and increasing crop productivity is an important task for world agriculture. The most promising are ecologically safe technologies based on using plant hormones and biostimulants of natural origin [32, 36-38, 87, 91] as alternative means compared with toxic for environment and human health pesticides, fungicides and herbicides [9, 10]. Another perspective strategy is the creation of new chemical or natural plant growth regulators on the base of low molecular weight heterocyclic compounds as effective substitutes of phytohormones and traditional growth regulators, in favor of this strategy witness our previous researches [92] and works of other authors [73-86].

Numerous studies devoted to impact of different classes of growth regulating compounds on maize growth and development have been conducted; the obtained results confirmed usefulness of application of synthetic or natural growth regulators as well as organic and mineral fertilizers for improving of maize growth and quality of grain yield [63-72; 106-119]. The elaboration of new effective growth regulators for intensification of maize growth and improvement of product quality is very actual problem.

Based on the literature data and results of our previous researches in this work we studied impact of low molecular weight heterocyclic compounds derivatives of pyrimidine, pyrazole and isoflavones on acceleration of seed germination and maize vegetative growth. It was found that all tested compounds used at very low concentrations ranging from 10^{-9}M - 10^{-10}M in water solution showed high growth stimulating activity on the maize seedlings. The highest growth stimulating activity showed compounds derivatives of isoflavones and pyrimidine, the lower stimulating activity showed derivatives of pyrazole. The natural and synthetic auxins IAA and NAA used at the same concentrations ranging from 10^{-9}M - 10^{-10}M in water solution showed similar or lower growth stimulating activity.

Taking into account the fact that plant growth is the result of the processes of cell differentiation, formation of tissue, organ and whole organism and these basic processes are controlled by genetic program and by phytohormones [32, 120, 121], it is possible to assumed that the high physiological activity of synthetic heterocyclic compounds, which is similar to activity of phytohormones auxins, may be based on their inducing effect on the plant cell elongation and division, and on the increased rate of metabolism in the plant cells. These processes result in acceleration of plant growth and development.

5. Conclusion

Obtained results confirmed perceptiveness of application of chemical low molecular weight heterocyclic compounds derivatives of pyrimidine, pyrazole and isoflavones used at the concentrations ranging from 10^{-9}M - 10^{-10}M in water solution as new effective stimulators of seed germination and vegetative growth of maize (*Zea mays* L.) in the agricultural practice.

6. References

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