Scholars Bulletin *(Chemistry)*

An Official Publication of "Scholars Middle East Publishers"
Dubai, United Arab Emirates
Website: http://scholarsbulletin.com/

ISSN 2412-9771 (Print)
ISSN 2412-897X (Online)

Application of Oxazole and Oxazolopyrimidine as New Effective Regulators of Oilseed Rape Growth

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Article History
Received: 10.03.2018
Accepted: 20.03.2018
Published: 30.03.2018

DOI:
10.21276/sb.2018.4.3.8

Abstract: The elaboration of new effective and ecologically friendly regulators improving growth and increasing yield of oilseed rape is an actual problem for modern agriculture. Our work was devoted to screening of new effective plant growth regulators among chemical low molecular weight heterocyclic compounds, derivatives of oxazole and oxazolopyrimidine to improve the germination of seeds and growth of seedlings of oilseed rape (*Brassica napus* L.) of cultivar Kalinivsky. As a result of the conducted experiments, the most effective synthetic compounds that showed a high stimulating effect when used in concentration 10^{-9}M on the growth of 21st-day-old oilseed rape seedlings were selected. It was found that biometric indices of 21st-day-old oilseed rape seedlings grown on the 10^{-9}M solution of derivatives of oxazole and oxazolopyrimidine were increased by an average to 11 - 30 % – by length of shoots, by an average to 8 - 68 % – by total number of roots, and by an average to 5 - 43 % – by total length of roots, as compared with similar indices of 21st-day-old oilseed rape seedlings grown on the distilled water (control) or on the 10^{-9}M solution of plant hormones auxins IAA (1*H*-Indol-3-ylacetic acid) and NAA (1-Naphthylacetic acid). The content of photosynthetic pigments in the leaves of 21st-day-old oilseed rape seedlings grown on the 10^{-9}M solution of derivatives of oxazole and oxazolopyrimidine was increased by an average to 14 - 20 % – by content of chlorophyll a, by an average to 15 - 21 % – by content of chlorophyll b, by an average to 16 – 18 % – by content of chlorophyll a+b, as compared with similar indices of 21st-day-old oilseed rape seedlings grown on the distilled water (control) and were increased by an average to 14 - 26 % – by content of carotenoids as compared with similar indices of 21st-day-old oilseed rape seedlings grown on the distilled water (control) or grown on the 10^{-9}M solution of IAA and NAA, respectively. The obtained results confirmed the possibility of using of derivatives of oxazole and oxazolopyrimidine as new effective regulators to improve oilseed rape growth.

Keywords: oilseed rape, growth regulators, oxazole and oxazolopyrimidine, auxins IAA and NAA.

INTRODUCTION

Oilseed rape (*Brassica napus* L.) is an important strategic energy and food crop cultivated in the economically developed countries including the USA, Canada, European Union, China, India, and Australia [1-9]. Oilseed rape is used for the production of edible vegetable oils, animal feed, and biodiesel [2, 10, 11].

Oilseed rape oil is useful for human nutrition for protection of cardiovascular diseases due to lower content of cholesterol and high content of most important cardioprotective substances including unsaturated fatty acids such as linoleic acid (21 %) and alpha-linolenic acid (11 %), plant sterols (0.53 – 0.97 %), and tocopherols (700 – 1,200 ppm) [2, 12, 13].

Rapeseed oil produced from wild seeds contains 50 % of potentially harmful for human health erucic acid and high levels of glucosinolates (mustard oil glycosides), that can be used as valuable and renewable raw material for production of a wide array of industrial products, as pesticides, anti-microbial, anti-fungicidal, anti-bacterial, and anti-virus agents for plant protection against pests and pathogens, and as bio-fumigants [11, 14 - 17].

Nowadays the plant breeders create the suitable for human nutrition and animal feed double low oilseed rape varieties containing decreased content of erucic acid in the rape oil to 0 % - 40 % and low level of glucosinolates, and vice versa increased content of linoleic acid to 15 – 20 % and linolenic acid to 8 % - 20 % [2, 9]. Recently, the European Food Safety

Authority allowed using rapeseed protein isolate as an important protein supplements to human foods [2, 18]. The oilseed rape oil glucosinolates can be used in medicine to prevent cancer due to their anti-cancer properties [2, 13, 18].

Oilseed rape oil-based derivatives are used for industrial purposes, including production of environmentally friendly and less toxic than traditional petroleum based derivatives: biofuels, printing inks, lubricants, stabilizers and processing aids, flame retardants in the manufacture of plastics, slip agents to prevent adhesion in polythene film, and anti-block, anti-static, plasticizing, and reactive agents used in the manufacture of polyamides and polyesters [2].

Oilseed rape meal proteins-based derivatives are also used as source for production of bioplastics, coatings, glue, adhesive, paper, cosmetic, emulsifie, as encapsulation agents for pharmaceuticals, agrochemicals and flavours, and as a combustion material. Rapeseed oil cake meal remaining after rapeseed oil production is enriched by high content of important amino acids such as methionine, cystine, and threonine, fatty acids, and minerals such as P, Ca, Mg, Mn and Se, therefore it is used as an animal feed and plant fertilizer [2, 7, 9-11, 18, 19].

Oilseed rape straw is used as animal bedding, animal feed, combustion, as a source for production of industrial fibre, and as a combustion material [2, 11].

Global climatic changes, soil contamination by industrial wastes and pesticides, pathogens and pests adversely affect the growth and decrease the yield of industrially important culture oilseed rape (*Brassica napus* L.) [5, 20, 21]. Today the natural and synthetic plant growth regulators, mineral fertilizers, and pesticides are widely used in agriculture sector of economically developed countries to accelerate oilseed rape growth and increase yield, and to protect from pests and adverse environmental factors [5, 22 – 31]. Nevertheless, the elaboration of new effective and ecologically friendly plant growth regulators on the base of natural and synthetic compounds to improve growth and development of this strategic energy and food crop is an actual problem for modern agriculture [32 - 34].

The most innovative approach to solve this actual problem is the elaboration of new plant growth regulators and plant protection agents on the basis of chemical low molecular weight heterocyclic compounds, derivatives of pyridine, pyrimidine, pyrazole, triazole, and oxazole [31, 35 – 48]. Today the new biologically active compounds are synthesized on the base of low molecular weight five and six-membered heterocyclic compounds in the Institute of Bioorganic Chemistry and Petrochemistry of NAS of Ukraine. Our previously conducted researchers showed the advisability of application of low molecular weight synthetic heterocyclic compounds, derivatives of pyridine, pyrimidine, pyrazolotriazine, oxazole and oxazolopyrimidine to accelerate growth of various important agricultural crops during their vegetation [49 – 55].

The present work is aimed to study the effect of new chemical low molecular weight heterocyclic compounds, derivatives of oxazole and oxazolopyrimidine on regulation of seed germination and growth of oilseed rape (*Brassica napus* L.) of cultivar Kalinivsky during plant vegetative stage.

MATERIALS AND METHODS

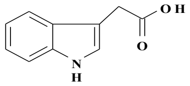
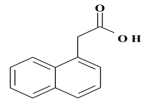
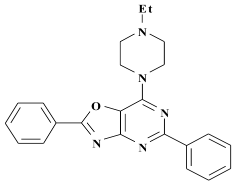
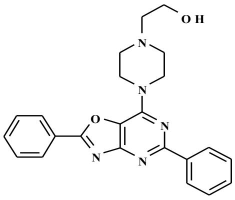
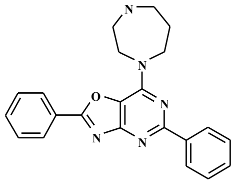
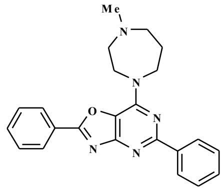
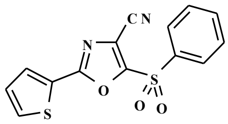
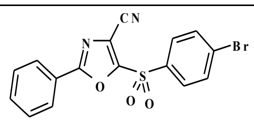
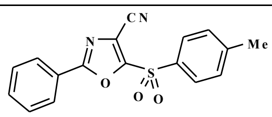
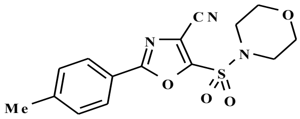
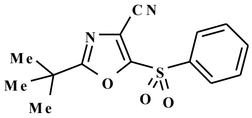
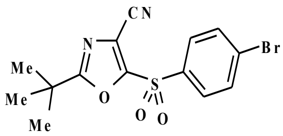
Chemical structure of derivatives of oxazole and oxazolopyrimidine and phytohormones

In the laboratory conditions we studied the growth regulatory activity of chemical compounds, derivatives of oxazole and oxazolopyrimidine on intensification of germination of seeds and growth of oilseed rape (*Brassica napus* L.) seedlings of cultivar Kalinivsky during the 21st day. These chemical compounds were synthesized at the Department for chemistry of bioactive nitrogen-containing heterocyclic compounds of Institute of Bioorganic Chemistry and Petrochemistry of NAS of Ukraine.

The growth regulatory activity of chemical compounds was compared with growth regulatory activity of plant hormones auxins IAA (1*H*-Indol-3-ylacetic acid) and NAA (1-Naphthylacetic acid).

The chemical structure, name and relative molecular weights of derivatives of oxazole and oxazolopyrimidine (the compounds № 1 - 10) and phytohormones auxins IAA and NAA are shown in Table 1.

Table-1: The structure, name and relative molecular weight of tested chemical compounds

№	Chemical structure of tested compound	Chemical name and relative molecular weight of tested compound
IAA		(1*H*-Indol-3-ylacetic acid), MW=175.19
NAA		(1-Naphthylacetic acid), MW=186.21
1		7-(4-Ethylpiperazin-1-yl)-2,5-diphenyl[1,3]oxazolo[4,5-*d*]pyrimidine, MW=385.47
2		2-[4-(2,5-Diphenyl[1,3]oxazolo[4,5-*d*]pyrimidin-7-yl)piperazin-1-yl]ethanol, MW=401.47
3		7-(1,4-Diazepan-1-yl)-2,5-diphenyl [1, 3]oxazolo[4,5-*d*]pyrimidine, MW=371.45
4		7-(4-Methyl-1,4-diazepan-1-yl)-2,5-diphenyl[1,3]oxazolo[4,5-*d*]pyrimidine, MW=385,47
5		5-(Phenylsulfonyl)-2-(2-thienyl)-1,3-oxazole-4-carbonitrile, MW=316.36
6		5-[(4-Bromophenyl)sulfonyl]-2-phenyl-1,3-oxazole-4-carbonitrile, MW=389.23
7		5-[(4-Methylphenyl)sulfonyl]-2-phenyl-1,3-oxazole-4-carbonitrile, MW=324.36
8		2-(4-Methylphenyl)-5-(morpholin-4-ylsulfonyl)-1,3-oxazole-4-carbonitrile, MW=333.37
9		2-*tert*-Butyl-5-(phenylsulfonyl)-1,3-oxazole-4-carbonitrile, MW=290.34
10		5-[(4-Bromophenyl)sulfonyl]-2-*tert*-butyl-1,3-oxazole- 4-carbonitrile, MW=369.24

Plant growing conditions and treatment

Seeds of oilseed rape (*Brassica napus* L.) of cultivar Kalinivsky 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 derivatives of oxazole and oxazolopyrimidine, and phytohormones auxins IAA and NAA used at the same concentration 10^{-9}M. After this procedure the control and experimental seeds were placed in the thermostat for their germination in the darkness at the temperature 23 °C during 48 hours. 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 %. Comparative analysis of biometric indices of seedlings (i.e. number of germinated seeds (%), length of shoots (cm), total number of roots (pcs), total length of roots (mm)) was carried out at the 21st day after their sprouting according to the guideline [56].

The biometric indices determined in the 21st-day-old oilseed rape seedlings grown on the solution of chemical compounds, derivatives of oxazole and oxazolopyrimidine used at the concentration 10^{-9}M was expressed in % according to similar index determined in the control 21st-day-old oilseed rape seedlings grown on the distilled water (control), or 21st-day-old oilseed rape seedlings grown on the solution of phytohormones auxins IAA and NAA used at the same concentration 10^{-9}M.

Determination of photosynthetic pigments content in the oilseed rape seedlings

The total content of chlorophyll a, chlorophyll b, and carotenoids was determined in the leaves of 21st-day-old oilseed rape (*Brassica napus* L.) seedlings of cultivar Kalinivsky grown either on the distilled water (control), or on the water solution of chemical compounds, derivatives of oxazole and oxazolopyrimidine, and phytohormones auxins IAA and NAA used at the same concentration 10^{-9}M.

The sample (500 mg) of leaves isolated from control and experimental 21st-day-old oilseed rape seedlings 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 [57]:

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

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 tomato 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).

The index of content of chlorophyll a, chlorophyll b, and carotenoids determined in the leaves of 21st-day-old oilseed rape seedlings grown on the solution of derivatives of oxazole and oxazolopyrimidine used at the concentration 10^{-9}M was expressed in % according to similar index determined in the leaves of control 21st-day-old oilseed rape seedlings grown on the distilled water (control), or 21st-day-old oilseed rape seedlings grown on the solution of phytohormones auxins IAA and NAA used at the same concentration 10^{-9}M.

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 [58].

RESULTS

Impact of derivatives of oxazole and oxazolopyrimidine and phytohormones on growth of oilseed rape seedlings

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, development of flower and fruit, prevention of leaf abscission and delaying of leaf senescence [59 - 70].

In our work the regulatory effect of chemical compounds, derivatives of oxazole and oxazolopyrimidine, and phytohormones IAA and NAA used at the same concentration 10^{-9}M on germination of seeds and growth of oilseed rape (*Brassica napus* L.) seedlings of cultivar Kalinivsky during 21 days was studied.

The obtained results showed that all tested chemical compounds, derivatives of oxazole and oxazolopyrimidine revealed phytohormone-like regulatory effect on growth of roots and shoots on the 21st-day-old oilseed rape seedlings (Figure-1).

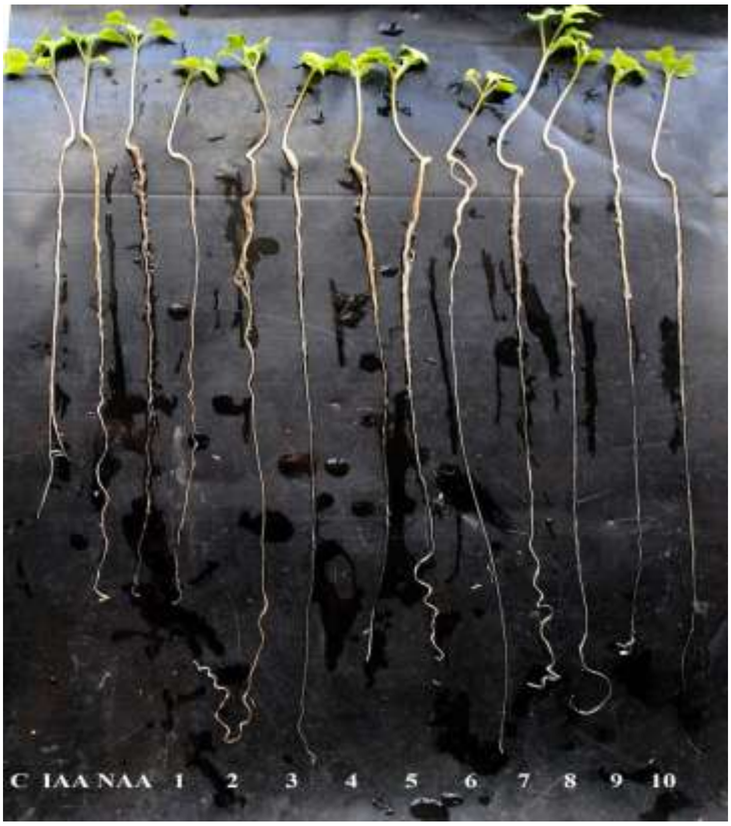


Figure-1 Effect of derivatives of oxazole and oxazolopyrimidine, and phytohormones IAA and NAA on growth of roots and shoots on the 21st-day-old oilseed rape (*Brassica napus* L.) seedlings of cultivar Kalinivsky. C – Control (distilled water), the compounds № 1 – 10 - the derivatives of oxazole and oxazolopyrimidine, auxins IAA - 1*H*-Indol-3-ylacetic acid and NAA - 1-Naphthylacetic acid

The comparative statistical analysis of biometric indices obtained on the 21st-day-old oilseed rape seedlings (i.e. number of germinated seeds (%), length of shoots (cm), total number of roots (pcs), total length of roots (mm)) showed that the biometric indices obtained on the 21st-day-old oilseed rape seedlings grown on the water solution of chemical compounds, derivatives of oxazole and oxazolopyrimidine used at the concentration 10^{-9}M were similar or higher than the biometric indices obtained on the 21st-day-old oilseed rape seedlings grown either on the distilled water (control), or on the water solution of auxins IAA and NAA used at the same concentration 10^{-9}M (Figure 2).

It was found that biometric indices obtained on the 21st-day-old oilseed rape seedlings grown on the 10^{-9}M solution of derivatives of oxazole and oxazolopyrimidine were increased by an average to 11 - 30 % – by length of shoots, by an average to 8 - 68 % – by total number of roots, and by an average to 5 - 43 % – by total length of roots, as compared with similar indices obtained on the 21st-day-old oilseed rape seedlings grown on the distilled water (control) or on the 10^{-9} M solution of plant hormones auxins IAA (1*H*-Indol-3-ylacetic acid) and NAA (1-Naphthylacetic acid) (Figure 2).

Among all tested chemical compounds, derivatives of oxazole and oxazolopyrimidine, some chemical compounds № 7, 9 and 10 revealed high growth regulatory activity on the indices of length of shoots which were increased by an average to 14 – 30 % as compared with similar indices obtained on the 21st-day-old oilseed rape seedlings grown on the distilled water (control), by an average to 11 - 28 % as compared with similar indices obtained on the 21st-day-old oilseed rape seedlings grown on the 10^{-9} M solution of plant hormone IAA (1*H*-Indol-3-ylacetic acid), and by an average to 12 - 29 % as compared with similar indices obtained on the 21st-day-old oilseed rape seedlings grown on the 10^{-9} M solution of plant hormone NAA (1-Naphthylacetic acid) (Figure 2).

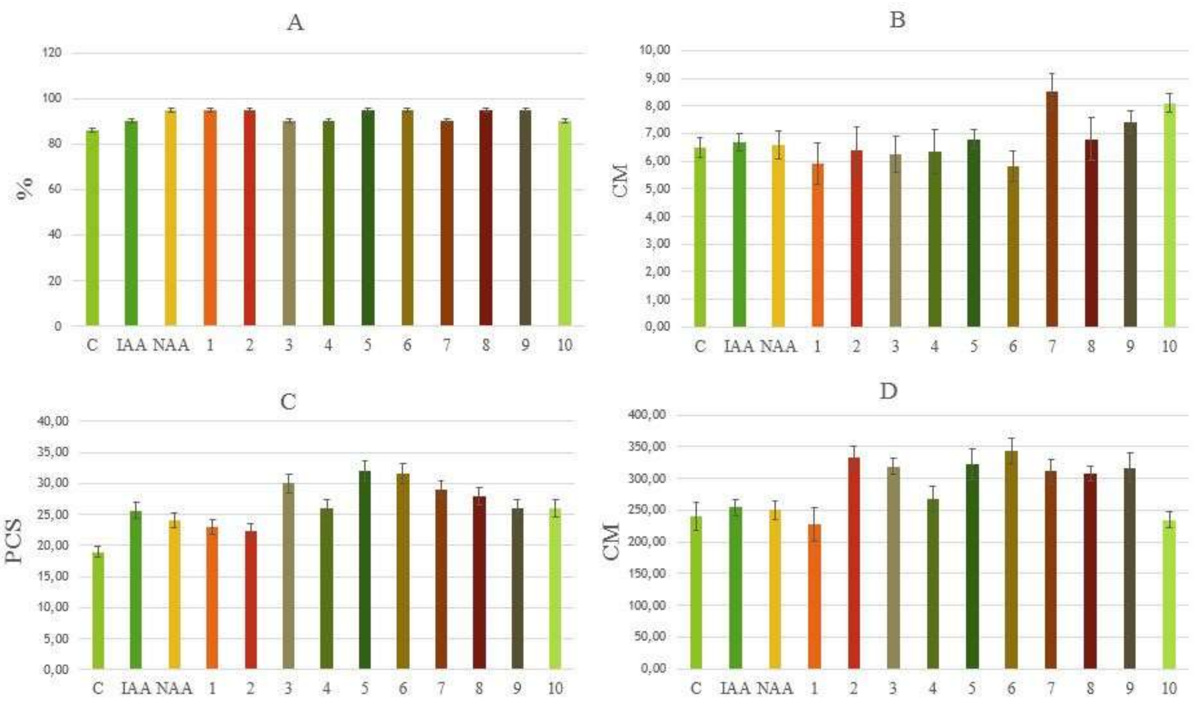


Figure-2 Effect of derivatives of oxazole and oxazolopyrimidine, and phytohormones IAA and NAA on biometric indices obtained on the 21st-day-old oilseed rape (*Brassica napus* L.) seedlings of cultivar Kalinivsky: A – number of germinated seeds (%); B – length of shoots (cm); C - total number of roots (psc); D - total length of roots (mm).

According to indices of total number of roots the highest growth regulatory activity among tested chemical compounds, derivatives of oxazole and oxazolopyrimidine revealed the compounds № 3, 5 and 6; the indices of total number of roots were increased by an average to 57 – 68 % as compared with similar indices obtained on the 21st-day-old oilseed rape seedlings grown on the distilled water (control), by an average to 17 – 25 % as compared with similar indices obtained on the 21st-day-old oilseed rape seedlings grown on the 10^{-9} M solution of plant hormone IAA (1*H*-Indol-3-ylacetic acid), and by an average to 25 – 33 % as compared with similar indices obtained on the 21st-day-old oilseed rape seedlings grown on the 10^{-9} M solution of plant hormone NAA (1-Naphthylacetic acid) (Figure 2).

The lower growth regulatory activity according to indices of total number of roots revealed the compounds № 1, 2, 4, 7, 8, 9 and 10; the indices of total number of roots were increased by an average to 18 – 53 % as compared with similar indices obtained on the 21st-day-old oilseed rape seedlings grown on the distilled water (control), by an average to 9 – 13 % as compared with similar indices obtained on the 21st-day-old oilseed rape seedlings grown on the 10^{-9} M solution of plant hormone IAA (1*H*-Indol-3-ylacetic acid), and by an average to 8 - 21 % as compared with similar indices obtained on the 21st-day-old oilseed rape seedlings grown on the 10^{-9} M solution of plant hormone NAA (1-Naphthylacetic acid) (Figure 2).

According to indices of total length of roots the highest growth regulatory activity among tested chemical compounds, derivatives of oxazole and oxazolopyrimidine revealed the compounds № 2, 3, 5 and 6; the indices of total length of roots were increased by an average to 33 – 43 % as compared with similar indices obtained on the 21st-day-old oilseed rape seedlings grown on the distilled water (control), by an average to 26 – 35 % as compared with similar indices obtained on the 21st-day-old oilseed rape seedlings grown on the 10^{-9} M solution of plant hormone IAA (1*H*-Indol-3-ylacetic acid), and by an average to 28 – 38 % as compared with similar indices obtained on the 21st-day-old oilseed rape seedlings grown on the 10^{-9} M solution of plant hormone NAA (1-Naphthylacetic acid) (Figure-2).

The lower growth regulatory activity according to indices of total length of roots revealed the compounds № 1, 4, 7, 8 and 9; the indices of total length of roots were increased by an average to 11 – 32 % as compared with similar indices obtained on the 21st-day-old oilseed rape seedlings grown on the distilled water (control), by an average to 5 – 25 % as compared with similar indices obtained on the 21st-day-old oilseed rape seedlings grown on the 10^{-9} M solution of plant hormone IAA (1*H*-Indol-3-ylacetic acid), and by an average to 7 – 27 % as compared with similar indices obtained on the 21^{st}-day-old oilseed rape seedlings grown on the 10^{-9} M solution of plant hormone NAA (1-Naphthylacetic acid) (Figure-2).

The study of relationship between chemical structure and plant growth regulatory activity of oxazole and oxazolopyrimidine derivatives showed that biological activity of these compounds was differentiated depending on their chemical structure. The highest regulatory activity on growth of oilseed rape seedlings during 21 days was revealed for the compounds № 2 and 3 belonging to condensed derivatives of oxazole, and the compounds № 5 and 6 belonging to the uncondensed 5-arylsulfonyl-substituted oxazoles.

The comparative analysis of growth regulatory activity of compounds № 1 and 2 showed that the compound № 2 containing 1-ethanol-piperazine substituent in the 7 position of oxazolopyrimidine revealed higher regulatory activity on growth of oilseed rape seedlings during 21 days; the lower regulatory activity revealed the compound № 1 containing 4-ethylpiperazine substituent in the 7 position of oxazolopyrimidine fragment. Probably, the presence of hydroxyl substituent increases the activity of chemical compound № 2.

The comparative analysis of growth regulatory activity of compounds № 3 and 4 showed that the compound № 3 , which does not contain methyl substituent in the diazepan fragment, revealed higher regulatory activity on growth of oilseed rape seedlings during 21 days; the lower regulatory activity revealed the compound № 4 containing methyl substituent in the diazepan fragment.

The comparative analysis of growth regulatory activity of compounds № 5 and 6 belonging to the uncondensed 5-arylsulfonyl-substituted oxazoles showed that the compound № 5 containing thiophene substituent in the 2 position of oxazole, revealed higher regulatory activity on growth of oilseed rape seedlings during 21 days; the lower regulatory activity revealed the compound № 6 containing phenyl substituent in the 2 position and 4-bromophenyl-sulfonyl substituent in the 5 position of oxazole.

The comparative analysis of growth regulatory activity of compounds № 6 and 7 showed the compound № 6 with bromine to be more active than compound № 7 without bromine.

The comparative analysis of growth regulatory activity of the compounds № 8, 9, and 10 belonging to uncondensed derivatives of oxazole, showed that the compound № 8 containing 4-methylphenyl substituent in the 2 position and morpholin-4-yl-sulfonyl substituent in 5 position of oxazole, and compound № 9 with *tert*-butyl substituent in the 2 position and phenylsulfonyl substituent in the 5 position of oxazole revealed higher regulatory activity on growth of oilseed rape seedlings during 21 days; the lower regulatory activity revealed the compound № 10 containing 4-bromophenylsulfonyl substituent in the 5 position and *tert*-butyl substituent in the 2 position of oxazole.

Thus, the conducted researches showed that all tested chemical compounds, derivatives of oxazole and oxazolopyrimidine used at the concentration 10^{-9}M revealed high growth regulating activity on germination of seeds and growth of oilseed rape (*Brassica napus* L.) seedlings of cultivar Kalinivsky during 21 days. Obviously, that the high growth regulatory activity of derivatives of oxazole and oxazolopyrimidine is explained by their auxin-like and cytokinin-like stimulating effects on plant cell elongation, proliferation and differentiation, that are the basic processes of plant growth and development [59 - 70].

Impact of derivatives of oxazole and oxazolopyrimidine and phytohormones on content of photosynthetic pigments in the leaves of oilseed rape seedlings

As is known phytohormones cytokinins take an important part in regulation of biosynthesis in plant cells of the major photosynthetic pigments such as chlorophylls and carotenoids playing a key role in photosynthetic processes and photoprotection in plants, and providing plant productivity [57, 59, 61, 62, 68, 71-74].

In our experiments the phytohormone-like regulatory effects of chemical compounds, derivatives of oxazole and oxazolopyrimidine used at the concentration 10^{-9}M, and phytohormones auxins IAA and NAA used at the same concentration 10^{-9}M on synthesis of the major photosynthetic pigments (chlorophyll a, chlorophyll b, and carotenoids) in the 21^{st}-day-old oilseed rape (*Brassica napus* L.) seedlings of cultivar Kalinivsky were studied.

It was found that among all tested chemical compounds, derivatives of oxazole and oxazolopyrimidine, the highest regulatory activity revealed the chemical compounds № 4, 6, 8 and 9; the content of chlorophyll a and chlorophyll b in the leaves of 21^{st}-day-old oilseed rape seedlings grown on the 10^{-9} M solution of these compounds was increased by an average to 14 - 20 % – by content of chlorophyll a, by an average to 15 - 21 % – by content of chlorophyll b, by an average to 16 – 18 % – by content of chlorophyll a+b, as compared with similar indices of 21^{st}-day-old oilseed rape seedlings grown on the distilled water (control) (Figure-3).

At the same time the content of chlorophyll a and chlorophyll b in the leaves of 21st-day-old oilseed rape seedlings grown on the 10^{-9} M solution of chemical compounds № 4, 6, 8 and 9 did not increase significantly as compared with similar indices of 21st-day-old oilseed rape seedlings grown on the 10^{-9} M solution of plant hormone IAA (1*H*-Indol-3-ylacetic acid) or on the 10^{-9} M solution of plant hormone NAA (1-Naphthylacetic acid) (Figure 3).

It was also found that the content of carotenoids in the leaves of 21st-day-old oilseed rape seedlings grown on the 10^{-9} M solution of chemical compounds № 4, 6, 8 and 9 was increased by an average to 14 - 26 % as compared with similar indices of 21st-day-old oilseed rape seedlings grown on the distilled water (control) or grown on the 10^{-9} M solution of IAA and NAA, respectively (Figure 3).

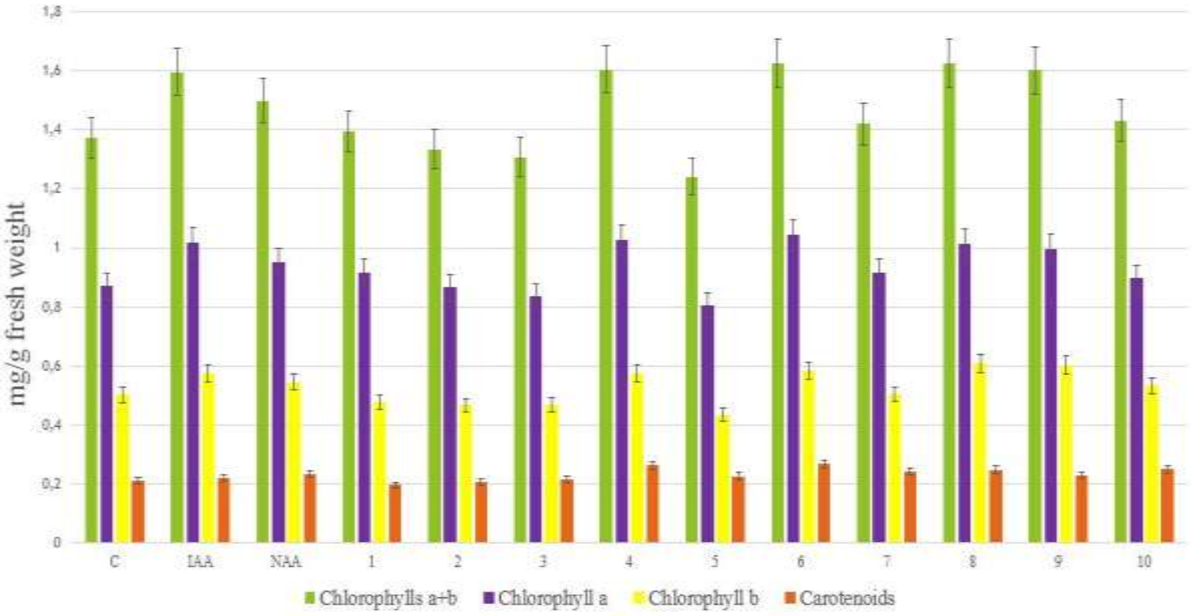


Figure-3 Effect of derivatives of oxazole and oxazolopyrimidine, and phytohormones IAA and NAA on content of chlorophyll a, chlorophyll b and carotenoids in the leaves of 21st-day-old oilseed rape (*Brassica napus* L.) seedlings of cultivar Kalinivsky

The study of relationship between chemical structure and regulatory activity of oxazole and oxazolopyrimidine derivatives on synthesis of photosynthetic pigments (chlorophylls a, b, and carotenoids) in the leaves of 21st-day-old oilseed rape seedlings showed that the highest regulatory activity was revealed for derivatives of oxazolopyrimidine – the compound № 4 containing methyl substituent in the diazepan fragment. At the same time the compound № 3 without methyl group in the diazepan fragment, did not exhibited regulatory activity.

Among the oxazole derivatives the high regulatory activity was revealed for compounds № 6, 8, and 9 with different substituents in the 2 and CN-group in 4 position of oxazole ring and similar arylsulfonyl or sulfonylamide substituents in the 5 position of oxazole.

The comparative analysis of regulatory activity between non-condensed and condensed sulfonyl-substituted derivatives of oxazole showed that non-condensed compounds exhibited higher regulatory activity than condensed derivatives of oxazole.

Thus the obtained results proved the positive effect of chemical compounds № 4, 6, 8 and 9, derivatives of oxazole and oxazolopyrimidine on increasing of content of photosynthetic pigments (chlorophylls a, b, and carotenoids) in the leaves of 21st-day-old oilseed rape seedlings playing an important role in photosynthetic processes and providing plant productivity [57, 71 - 74].

Possibly this fact is explained by cytokinin-like effect of pyrimidine derivatives on increasing of synthesis of chlorophylls and carotenoids and on delaying chlorophyll breakdown in in the leaves of 21st-day-old oilseed rape seedlings [59, 61, 62, 68, 71 - 74].

CONCLUSION

Screening of new effective regulators among chemical compounds, derivatives of oxazole and oxazolopyrimidine to accelerate vegetative growth of oilseed rape (*Brassica napus* L.) of cultivar Kalinivsky was conducted. The growth regulatory activity of chemical compounds was compared with growth regulatory activity of plant hormones auxins IAA (1*H*-Indol-3-ylacetic acid) and NAA (1-Naphthylacetic acid). The conducted researchers showed that all tested chemical compounds, derivatives of oxazole and oxazolopyrimidine used at the concentration 10^{-9}M revealed the high stimulating effect on the growth of oilseed rape seedlings during 21 days. The biometric indices obtained on the 21st-day-old oilseed rape seedlings grown on the 10^{-9}M solution of derivatives of oxazole and oxazolopyrimidine were increased as compared with similar indices obtained on the 21st-day-old oilseed rape seedlings grown on the distilled water (control) or on the 10^{-9} M solution of plant hormones auxins IAA and NAA. The study of relationship between chemical structure and plant growth regulatory activity of derivatives of oxazole and oxazolopyrimidine showed that growth regulatory activity of these compounds varied depending on their chemical structure. The highest growth regulatory activity on growth of oilseed rape seedlings during 21 days exhibited the derivatives of oxazolopyrimidine – the compounds № 2 and 3 belonging to condensed derivatives of oxazole, and the compounds № 5 and 6 belonging to the uncondensed 5-arylsulfonyl-substituted oxazoles. It was also found that compound № 4 – derivative of oxazolopyrimidine and compounds № 6, 8, and 9 – derivative of oxazole showed the high regulatory activity on increasing of synthesis of photosynthetic pigments (chlorophylls a, b, and carotenoids) in the leaves of 21st-day-old oilseed rape seedlings. The content of photosynthetic pigments in the leaves of 21st-day-old oilseed rape seedlings grown on the 10^{-9}M solution of chemical compounds № 4, 6, 8, and 9 was increased as compared with similar indices of 21st-day-old oilseed rape seedlings grown on the distilled water (control) or on the 10^{-9}M solution of IAA and NAA, respectively. The obtained results proved the possibility of application of chemical compounds, derivatives of oxazole and oxazolopyrimidine as new effective regulators to improve the vegetative growth of oilseed rape (*Brassica napus* L.) of cultivar Kalinivsky.

Conflict of interest

Authors stated that there is no conflict of interest.

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