

# Synthesis of Amidophosphates Based on 1-Ethynyl-1-Aminocyclohexane Upon Microwave Activation and their Biological Activity

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## Abstract

The researches for developing the methods for synthesizing new functionally substituted derivatives of alicyclic dialkylamidophosphates, establishing their structure, and searching for promising biologically active compounds in their series, are modern and relevant. The given study aimed to develop the synthesis of amidophosphates based on the example of phosphorylation of 1-ethynyl-1-aminocyclohexane with dialkyl phosphites in the presence of triethylamine in carbon tetrachloride in the Atherton-Todd reaction conditions using microwave irradiation of the reaction mixture. The reaction of 1-ethynyl-1-aminocyclohexane with dialkyl phosphites was carried out in a CCl<sub>4</sub> excess at an equimolar ratio of reagents, triethylamine was used as an HCl acceptor. The highest yields of dialkyl-N-(1-ethynylcyclohexan-1-yl)amidophosphates were achieved by adding equimolar amounts of dialkyl phosphites to the mixture of 1-ethynyl-1-aminocyclohexane, triethylamine, and CCl<sub>4</sub> followed by the subsequent activation of the mixture in a microwave reactor (MAS-II Plus MW) (MW 102 W, 115 °C, microwave irradiation time was 3–5 min). The composition and structure of the obtained compounds were proved by elemental analysis, IR, <sup>1</sup>H, <sup>13</sup>C, <sup>31</sup>P NMR spectroscopy, and X-ray diffraction analysis (XRD). The biological tests carried out in laboratory and field conditions allowed identifying diethyl-N-(1-ethynylcyclohexan-1-yl)amidophosphate among the synthesized compounds, which produces a high growth-regulating effect on the growth, development, and yield of agricultural crops.

## 1. Introduction

Among numerous organophosphorus compounds, the phosphorus-containing derivatives of the alicyclic series are of particular interest, among which many valuable substances with practically useful properties have been synthesized. They can be used in various chemical transformations, and are also useful objects for studying some theoretical issues in organic chemistry [1–5]. Although the number of studies in the field of organophosphorus compounds is ever increasing, some interesting classes of organophosphorus derivatives of

alicyclic acetylene-containing amines with various substituents both in the cycle and at the phosphorus atom, remain understudied. The compounds of this class are always of interest to researchers due to the variety of chemical transformations and the prospect of their use in various fields of science and technology, which stimulates the development of new methods for the synthesis of their polyfunctional derivatives [4–7].

However, phosphorylated acetylene-containing amines have been studied to a much lesser degree. In this regard, it is important to develop useful synthesis methods and to study the properties of new phosphorylated acetylenic amines. The presence of several reactive centers in such compounds predetermines great synthetic possibilities and in-

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teresting biological properties [8–11]. Thus, the research for developing the methods for synthesizing new functionally substituted derivatives of alicyclic dialkylamidophosphates, establishing their structure, and searching for promising biologically active compounds in their series, are modern and relevant.

This research aims at developing highly efficient methods for the preparation of functionally substituted acetylene-, nitrogen-, and phosphorus-containing amines of the alicyclic series. The conduction of this study has been dictated by an increased interest in the methods for the synthesis of acetylenic amines with unsaturated bonds, which greatly expands the research work for the preparation of their modified derivatives with potential biological activity. The aim of this study has been the development of the synthesis of amidophosphates in the example of phosphorylation of 1-ethynyl-1-aminocyclohexane with dialkyl phosphites in the presence of triethylamine in carbon tetrachloride under the Atherton-Todd reaction conditions, using microwave irradiation.

Thus, it can be noted that the chemistry of N-phosphorylated derivatives successfully continues its development with the emergence of new fruitful directions and methodological approaches. Classical problems related to the mechanism of the Atherton-Todd reaction have a new understanding and development due to the involvement of modern physical methods and theoretical and experimental material which creates the prospect of further developing organophosphorus compound area.

## 2. Experimental

The IR spectra were recorded on a Bruker Alfa spectrometer in the range of 400–3600  $\text{cm}^{-1}$ . The  $^1\text{H}$ ,  $^{13}\text{C}$ , and  $^{31}\text{P}$  NMR spectra were recorded on a Bruker AVANCE II-400 spectrometer with an operating frequency of 400.13 MHz, relative to the residual proton signals from the deuterated solvent ( $\text{CDCl}_3$ ).  $\text{H}_3\text{PO}_4$ , 85% was used as the external standard. The microwave synthesis was carried out in a MAS-II Plus microwave reactor (MW 102 W, 115 °C), (Sineo, China). The X-Ray diffraction data were collected at 296 K on a Bruker D8 QUEST with PHOTON II CCD diffractometer (Bruker AXS, Ettlingen, Germany), using graphite monochromated  $\text{MoK}_\alpha$  ( $\lambda = 0.71073 \text{ \AA}$ ) radiation and  $\omega$ -scan rotation. The melting points were determined on a Boetius apparatus. The elemental analysis was performed on an EA 1108 CarloErba

instrument. The reaction progress was monitored by thin-layer chromatography (TLC) on the plates with aluminum oxide in various solvent systems, the developer was iodine.

**Dimethyl-N-(1-ethynylcyclohex-1-yl)amidophosphate (5).** 0.01 mol (1.10 g, 0.92 ml) of dimethyl phosphite (**2**), 0.02 mol (3.08 g, 2.11 ml) of carbon tetrachloride, 0.015 mol (1.52 g, 1.08 ml) of triethylamine and 0.01 mol (1.24 g, 1.36 ml) of 1-ethynyl-1-aminocyclohexane (**1**) was placed in a 25 ml open flat-bottomed flask. The reaction was carried out in a MAS-II Plus microwave reactor for 3–5 min. The reaction progress was monitored by the TLC in the benzene-ethanol 10:1 system, Rf 0.61. After cooling, the solvent was evaporated on a rotary evaporator, and the resulting amidophosphate (**5**) was recrystallized from acetone. The yield: 2.12 g (92%), white powder, m.p. 111–112 °C. The IR spectrum ( $\nu$ ,  $\text{cm}^{-1}$ ): 3180 (NH), 3261 ( $\equiv\text{CH}$ ), 2106 ( $\text{C}\equiv\text{C}$ ), 1224 (P=O), 1033 (P-O-C).  $^1\text{H}$  NMR (600 MHz, Chloroform-*d*),  $\delta$  (ppm): 3.74 (d,  $J = 11.3$  Hz, 6H), 3.17 (d,  $J = 7.7$  Hz, 1H), 2.41 (s, 1H), 2.00 (d,  $J = 10.7$  Hz, 2H), 1.67–1.53 (m, 7H), 1.22–1.13 (m, 1H).  $^{13}\text{C}$  NMR (101 MHz, Chloroform-*d*),  $\delta$  (ppm): 52.00 ( $\text{C}_1$ ); 39.86 ( $\text{C}_{2,6}$ ); 23.31 ( $\text{C}_{3,5}$ ); 25.46 ( $\text{C}_4$ ); 87.10 ( $\text{C}_7$ ), 72.37 ( $\text{C}_8$ ), 53.43 ( $\text{C}_{9,10}$ ).  $^{31}\text{P}$  NMR,  $\delta$ , m.d.: 8.55. Anal. Calc. for  $\text{C}_{10}\text{H}_{18}\text{NO}_3\text{P}$ , %: C, 51.95; H, 7.79; N, 6.06; P, 13.42. Found., %: C, 52.23; H, 7.53; N, 5.86; P, 13.54.

**Diethyl-N-(1-ethynylcyclohex-1-yl)amidophosphate (6).** 0.01 mol (1.38 g, 1.28 ml) of diethyl phosphite (**3**), 0.02 mol (3.08 g, 2.11 ml) of tetrachloride carbon, 0.015 mol (1.52 g, 1.08 ml) of triethylamine, and 0.01 mol (1.24 g, 1.36 ml) of 1-ethynyl-1-aminocyclohexane (**1**) was placed in a 25 ml open flat-bottomed flask. The reaction was carried out in a MAS-II Plus microwave reactor for 3–5 min. The reaction progress was monitored by the TLC in the benzene-ethanol 10:1 system, Rf 0.69. After cooling, the solvent was evaporated on a rotary evaporator, and the resulting amidophosphate (**6**) was recrystallized from petroleum ether (40–70 °C). The yield: 2.35 g (91%), white powder, m.p. 50–51 °C. The IR spectrum,  $\nu$ ,  $\text{cm}^{-1}$ : 3175 (NH), 3229 ( $\equiv\text{CH}$ ), 2107 ( $\text{C}\equiv\text{C}$ ), 1209 (P=O), 1031 (P-O-C).  $^1\text{H}$  NMR (400 MHz, Chloroform-*d*)  $\delta$  4.15–4.08 (m, 4H), 2.93 (d,  $J = 7.2$  Hz, 1H), 2.40 (s, 1H), 2.02 (d,  $J = 5.9$  Hz, 2H), 1.62 (dd,  $J = 20.8, 9.3$  Hz, 7H), 1.34 (t,  $J = 7.1$  Hz, 6H).  $^{13}\text{C}$  NMR (101 MHz, Chloroform-*d*)  $\delta$  51.93 ( $\text{C}_1$ ); 39.80 ( $\text{C}_{2,6}$ ); 23.25 ( $\text{C}_{3,5}$ ); 24.21 ( $\text{C}_4$ ); 87.44 ( $\text{C}_7$ ); 73.48 ( $\text{C}_8$ ); 62.59 ( $\text{C}_{9,11}$ ); 61.14 ( $\text{C}_{10,12}$ ).  $^{31}\text{P}$  NMR,  $\delta$ , m.d.: 8.00. Anal. Calc. for  $\text{C}_{12}\text{H}_{22}\text{NO}_3\text{P}$ , %: C,

55.59; H, 8.49; N, 5.40; P, 11.96. Found., %: C 55.23; H 8.53; N 5.66; P 11.54.

**Di( $\beta$ -chloroethyl)-N-(1-ethynylcyclohex-1-yl)amidophosphate (7).** It was obtained similarly. The reaction progress was monitored by the TLC in the benzene-ethanol 10:1 system,  $R_f$  0.70. The yield: 3.18 g (97%), white powder, m.p. 39–40 °C. The IR spectrum,  $\nu$ ,  $\text{cm}^{-1}$ : 3191 (NH), 3274 ( $\equiv\text{CH}$ ), 2106 ( $\text{C}\equiv\text{C}$ ), 1233 ( $\text{P}=\text{O}$ ), 1032 ( $\text{P}-\text{O}-\text{C}$ ).  $^1\text{H}$  NMR (400 MHz, Chloroform- $d$ )  $\delta$  4.19 (s, 4H), 3.82 (d,  $J$  = 8.0 Hz, 2H), 3.65 (t,  $J$  = 5.1 Hz, 4H), 2.38 (s, 1H), 1.94 (s, 2H), 1.54 (s, 7H).  $^{13}\text{C}$  NMR (101 MHz, Chloroform- $d$ )  $\delta$  52.29 ( $\text{C}_1$ ); 39.87 (d,  $J$  = 5.1 Hz,  $\text{C}_{2,6}$ ); 23.29 ( $\text{C}_{3,5}$ ); 25.44 ( $\text{C}_4$ ); 87.08 ( $\text{C}_7$ ), 72.76 ( $\text{C}_8$ ), 66.44 (d,  $J$  = 4.9 Hz,  $\text{C}_{9,11}$ ); 43.16 (d,  $J$  = 7.7 Hz,  $\text{C}_{10,12}$ ).  $^{31}\text{P}$  NMR,  $\delta$ , m.d.: 6.50. Anal. Calc. for  $\text{C}_{12}\text{H}_{20}\text{NO}_3\text{PCl}_2$ , %: C, 43.90; H, 6.10; N, 4.27; P, 9.45. Found., %: C, 43.87; H, 6.59; N, 4.59; P, 9.75.

### 3. Results and discussion

Alicyclic amines are widely used in the synthesis of various functional organophosphorus derivatives of aminocyclohexanoic acids [6–11]. The cyclohexylamine derivatives are of interest as promising neurotropic compounds and anti-inflammatory preparations [12, 13]. The search for new conditions for the Atherton-Todd reaction is being continued at present. Despite the extensive experimental material, the Atherton-Todd reaction has not exhausted its synthetic possibilities both in terms of using new nucleophiles, and modernization of the individual process stages. Therefore, the research in this area is relevant. To date, among the phosphorylated derivatives of alicyclic and acetylene-containing amines, substances with a high biological activity have been found [14–18].

Previously, we showed [15, 16] that interaction of dialkyl phosphites with acetylene-containing amines under the conditions of the classical four-component one-stage Atherton-Todd reaction made it possible to obtain the target amidophosphates in good yields. However, the process could be complicated by a number of side reactions, in particular, the formation of pyrophosphates and phosphates [19]. The authors of the work [20], when studying the phosphorylation of amino(aryl) methylphosphonates under the conditions of the Atherton-Todd reaction, have noted that the effect of the microwave radiation [21, 22] on the reaction mass leads to an increase in the reaction rate and an increase in the yield of the end products, which, in their opinion, is an indirect confirmation of the

involvement of the associates with a charge transfer between amine and carbon tetrachloride in the synthesis of amidophosphates, and its subsequent decomposition under the effect of the microwave energy with the obtaining of the target products.

We have continued the study of the basic and applied aspects of the condensation of dialkylphosphorous acids with 1-ethynyl-1-aminocyclohexane, and have developed the optimal preparative conditions for its phosphorylation under the conditions of the Atherton-Todd reaction, using the microwave irradiation.

Dimethyl – (2), diethyl – (3) and di( $\beta$ -chloroethyl)phosphites (4) have been chosen as the initial dialkyl phosphites.

The reaction of 1-ethynyl-1-aminocyclohexane (1) with dialkyl phosphites (2–4) was carried out in an excess of  $\text{CCl}_4$  at an equimolar ratio of the reagents; triethylamine was used as an HCl acceptor. In all cases, the interaction proceeded smoothly (Fig. 1). The highest yields of dialkyl-N-(1-ethynylcyclohexan-1-yl)amidophosphates (5–7) were achieved by adding the equimolar amounts of dialkyl phosphites (2–4) to the mixture of 1-ethynyl-1-aminocyclohexane (1), triethylamine and  $\text{CCl}_4$ , followed by the irradiation of the reaction mixture in a microwave reactor MAS-II Plus, the time of the microwave irradiation made up 3–5 min. The triethylamine hydrochloride, precipitated as a result of the reaction, was filtered off, and the filtrate was distilled off in a vacuum. The obtained amidophosphates (5–7) were white crystalline substances, easily purified by the recrystallization from petroleum ether. The individuality of the synthesized compounds was controlled by the thin-layer chromatography (TLC) on alumina of the II degree of activity (benzene:ethanol 10:1). The composition and structure of the obtained compounds were confirmed by the elemental analysis, IR,  $^1\text{H}$ ,  $^{13}\text{C}$ ,  $^{31}\text{P}$  NMR spectroscopy, and X-ray diffraction analysis (XRD). The physicochemical characteristics of the compounds (5–7) are presented in Table 1.

**Table 1**

The physicochemical characteristics and yields of dialkyl-N-(1-ethynylcyclohexan-1-yl)amidophosphates (5–7)

#	R	Yield, %	m.p. °C	$R_f$
5	$\text{CH}_3$	92	111-112	0.61
6	$\text{CH}_2\text{CH}_3$	91	50-51	0.69
7	$\text{CH}_2\text{CH}_2\text{Cl}$	97	39-40	0.70

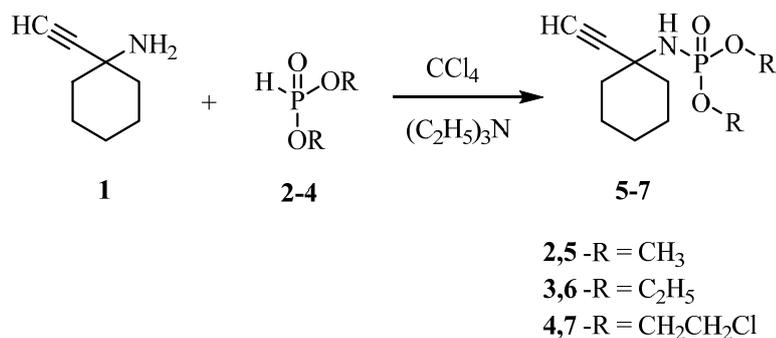


Fig. 1. Synthesis of dialkyl-N-(1-ethynylcyclohexan-1-yl) amidophosphates (**5-7**).

In the IR spectra of amidophosphates (**5-7**), the absorption bands were observed in the field of 1209–1233  $\text{cm}^{-1}$ , characteristic of the P=O group; the intense doublet absorption bands of the P-O-C bonds were observed in the range of 1031–1033  $\text{cm}^{-1}$ . The secondary amino group corresponded to the absorption bands in the field of 3175–3191  $\text{cm}^{-1}$ , respectively. The stretching vibrations were observed in the field of 2106, 2107  $\text{cm}^{-1}$ , which was characteristic of a triple bond (C $\equiv$ C). The stretching vibrations of the terminal acetylenic hydrogen ( $\equiv\text{CH}$ ) corresponded to the absorption bands in the field of 3261, 3229, 3274  $\text{cm}^{-1}$ , respectively.

In the  $^1\text{H}$  NMR spectra of the compounds (**5-7**), the proton signals of the amide group appeared as a doublet at 3.17, 3.82 ppm with the spin-spin splitting constant  $J = 7.7$  Hz, the ethynyl proton signal, manifested itself as a singlet at 2.38, 2.41 ppm with the spin-spin splitting constant  $J = 8.0$  Hz. The proton signals of the dialkoxyphosphoryl groups for (**5**) appeared as a doublet at 3.74 ppm. (d, 6H); for (**6**) – as a multiplet in the field of 4.08–4.15 ppm. (m, 4H). The proton signals of the cyclohexyl fragment for the compounds (**5-7**) resonated as multiplets in the field of 1.34 ppm (t, 6H), 1.67–1.53 ppm (m, 7H). The  $^{31}\text{P}$  NMR spectra of the reaction products (**5-7**) contained singlet signals at 8.55, 8.00, and 6.50 ppm, which corresponded to the resonance of the phosphorus nucleus in dialkyl amidophosphates.

### 3.1. The X-Ray Measurements

The X-ray diffraction study was carried out in the Laboratory of diffraction research methods of A.E. Arbuzov Institute of Organic and Physical Chemistry, FRC Kazan Scientific Center, Russian Academy of Sciences.

The crystallographic data: the crystals of the compound (**5**) ( $\text{C}_{10}\text{H}_{18}\text{NO}_3\text{P}$ ,  $M = 231.22$ ) were triclinic (Fig. 2, Table 2). With 108 K, the follow-

ing cell parameters were obtained:  $a = 6.6243(2)$ ,  $b = 8.9504(3)$ ,  $c = 11.0618(4)$  Å,  $\alpha = 108.282(1)$ ,  $\beta = 100.365(1)^\circ$ ,  $\gamma = 102.885(1)$ ,  $V = 584.53(3)$  Å<sup>3</sup>,  $Z = 2$ , the spatial group  $P-1$ ,  $d_{\text{calc}} = 1.314$   $\text{g}\cdot\text{cm}^{-3}$ ,  $\mu = 0.224$   $\text{mm}^{-1}$ ,  $F(000) = 248$ . The data were obtained on a Bruker D8 QUEST automatic diffractometer with a PHOTON II CCD detector [graphite monochromator,  $\lambda(\text{MoK}_\alpha) = 0.71073$  Å,  $\omega$ -scanning],  $2\theta < 60^\circ$ ,  $R_{\text{int}} = 0.032$ . 15873 reflections were measured, of which 3411 were independent, the number of the observed reflections with  $I > 2\sigma(I)$  was 3267, the final values of the divergence factors were  $R_0.0423$ ,  $wR_2 0.1133$ ,  $\text{GOF} = 1.29$ , and the number of the determined parameters was 142.

The crystallographic data: the crystals of the compound (**7**) ( $\text{C}_{12}\text{H}_{20}\text{Cl}_2\text{NO}_3\text{P}$ ,  $M = 328.16$ ) were monoclinic (Fig. 3, Table 2). With 108 K, the following cell parameters were obtained:  $a = 7.7198(4)$ ,  $b = 21.6218(12)$ ,  $c = 9.7966(5)$  Å,  $\beta = 111.054(2)^\circ$ ,  $V = 1526.05(14)$  Å<sup>3</sup>,  $Z = 4$ , the spatial group  $P2_1/n$ ,  $d_{\text{calc}} = 1.428$   $\text{g}\cdot\text{cm}^{-3}$ ,  $\mu = 0.533$   $\text{mm}^{-1}$ ,  $F(000) = 688$ . The data were obtained on a Bruker D8 QUEST automatic diffractometer with a PHOTON II CCD detector [graphite monochromator,  $\lambda(\text{MoK}_\alpha) = 0.71073$  Å,  $\omega$ -scanning],  $2\theta < 57.4^\circ$ ,  $R_{\text{int}} = 0.056$ . 31079 reflections were measured, of which 3965 were independent, the number of the observed reflections with  $I > 2\sigma(I)$  was 3602, the

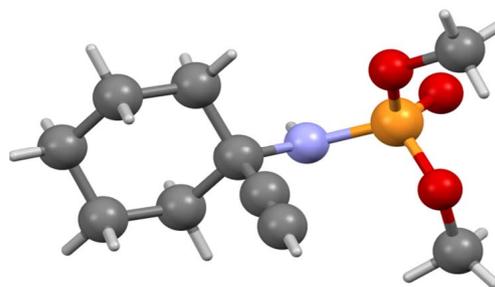


Fig. 2. The geometry of a molecule of dimethyl-N-(1-ethynylcyclohex-1-yl)amidophosphate (**5**) in a crystal.

**Table 2**  
Crystal data and structure refinement for complex **5** and **7**

	<b>5</b>	<b>7</b>
Empirical formula	C <sub>10</sub> H <sub>18</sub> NO <sub>3</sub> P	C <sub>12</sub> H <sub>20</sub> Cl <sub>2</sub> NO <sub>3</sub> P
Formula weight	231.22	328.16
Temperature	108 K	108 K
Space group	Triclinic	Monoclinic
Crystal System	P-1	P2 <sub>1/n</sub>
Unit Cell Dimensions	a = 6.6243(2) Å b = 8.9504(3) Å c = 11.0618(4) Å	a = 7.7198(4) Å b = 21.6218(12) Å c = 9.7966(5) Å
Volume	584.53(3)	1526.05(14)
Z	2	4
Density	1.314 g/cm <sup>3</sup>	1.428 g/cm <sup>3</sup>
Absorption coefficient	0.224 mm <sup>-1</sup>	0.533 mm <sup>-1</sup>
F(000)	248	688
Reflections collected	15873	31079
Independent reflections	3411 [ <i>R</i> <sub>int</sub> = 0.032]	3965 [ <i>R</i> <sub>int</sub> = 0.056]
GOF	1.29	1.08
Final R indices [ <i>I</i> > 2σ( <i>I</i> )]	<i>R</i> <sub>1</sub> 0.0423, <i>wR</i> <sub>2</sub> 0.1133	<i>R</i> <sub>1</sub> 0.0307, <i>wR</i> <sub>2</sub> 0.0786

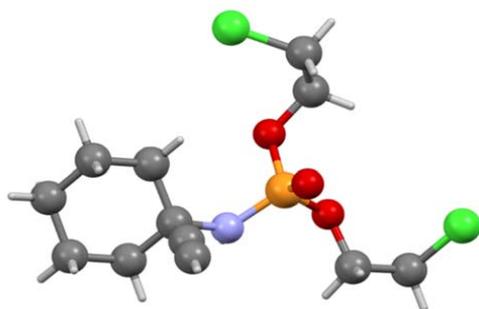


Fig. 3. The geometry of a molecule of di(β-chloroethyl)-N-(1-ethynylcyclohex-1-yl)amidophosphate (**7**) in a crystal.

final values of the divergence factors were *R*0.0307, *wR*<sub>2</sub> 0.0786, GOF = 1.08, the number of the determined parameters was 176.

The absorption recording was carried out, using the SADABS program [23]. The structure was interpreted by the direct method, using the SIR program [24], and it was refined in the isotropic and anisotropic approximations, using the SHELXL-97 program [25]. All hydrogen atoms were placed in the calculated positions, which were refined according to the rider scheme. All calculations were performed, using the WinGX [26] and APEX2 [27] programs. The drawings and analysis of the intermolecular contacts were made, using the PLATON program [28]. The crystallographic data of struc-

tures (**5**) and (**7**) were deposited in the Cambridge Crystallographic Database (<http://www.ccdc.cam.ac.uk>).

### 3.2. The study of the synthesized compounds for a growth-regulating activity

The study of the effect of amidophosphate (**6**) of diethyl-N-(1-ethynylcyclohexane-1-yl)amidophosphate (BA-4) on the growth, development and yield of carrots, red beets and potatoes was carried out under the laboratory conditions at the Laboratory of Technology for Cultivating Vegetable and Cucurbits Crops of the “Kazakh Research Institute of Fruit and Vegetable Growing”, and under the field conditions, on the experimental field of the Chair of Fruit, Vegetable, and Nut Growing of the “Kazakh National Agrarian University”.

Under the laboratory conditions, the optimal growth-activating concentrations of the BA-4 were determined: the study of the effect of the BA-4 on the germination energy and germinating capacity of the seeds of carrots (Fig. 4), red beets (Fig. 5) and on the budding of potato tubers. The concentrations of the preparation varied from 0.001 to 0.0001%. The optimal active concentrations of the preparation were further studied, based on the crop growth, development and yield under the field conditions.

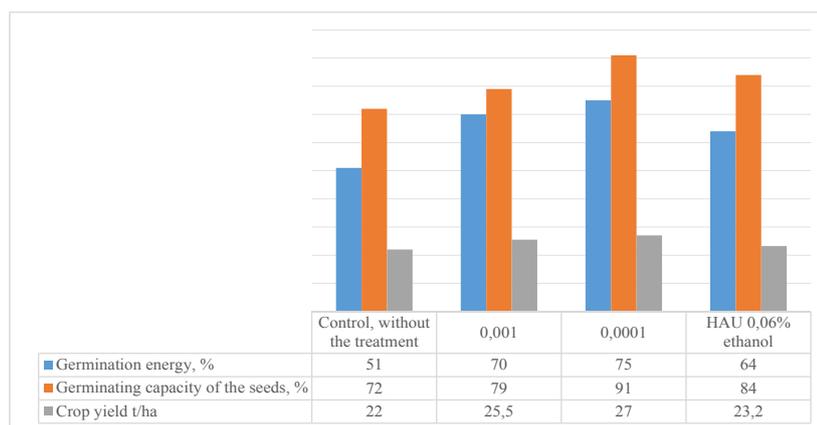


Fig. 4. The effect of the BA-4 on the germination energy, germinating capacity and crop yield of the “Alau” carrots variety.

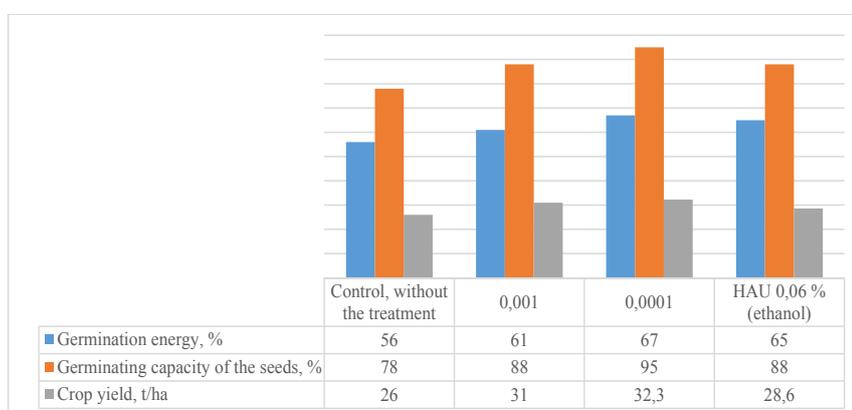


Fig. 5. The effect of the BA-4 on the germination energy, germinating capacity and crop yield of the “Kyzyl Kuren” red beets variety.

The plants, grown from the treated tubers, and were growing and developing better, were marked by a larger mass of the tops. As it could be, the weight of the tops in the variant, where the tubers were treated with BA-4 before planting, from the beginning of the vegetation season, exceeded the weight of the tops in the control variant: under the effect of the preparation in the concentration of 0.0001% at the first recording, the weight of the tops, as compared with the control variant, was more by 130.0 g, at the second recording – by 135.0 g; in the Extrasol standard (10%) – by 17.0 and 30.0 g. An increase in the mass of the aerial parts of the plants was observed before the end of the vegetation season.

The crop formation depended not only on the assimilation surface of the potato plants but also on the number of the formed tubers. As could be seen from Table 3, the studied preparation had a positive effect on the process of tuberization. So, at the first determination term (on the 45th day after germination), there were 6.1 pcs of tubers in the

control variant, 8.0 pcs of tubers in the variant with the BA-4 in the concentration of 0.001%, and 9.1 pcs of tubers in the concentration of 0.0001%, and 6.5 pcs of tubers – in the version with ethanol.

At the second determination term (on the 60th day after germination), 1 bush accounted for 7.0 pcs of tubers in the control variant, 8.6 pcs of tubers in the concentration of 0.001%, and 11.5 pcs of tubers in the concentration of 0.0001%, in the variant with the BA-4, respectively; 8.3 pcs of tubers – in the version with ethanol.

The active growth and development of potatoes had a positive effect on the process of tuberization, which ultimately led to an increase in potato yields (Table 4). The data in the Table show that the treatment of the tubers with BA-4 in the concentration of 0.001% increases the potato yield by 4.3 t/ha or 18.9%, as compared with the control variant; and in the concentration of 0.0001% – by 7.3 t/ha or 32.2%. The treatment of the tubers with the Extrasol standard preparation (10.0%) increases the potato yield by 2.3 t/ha (10.1%).

**Table 3**  
The effect of a BA-4 on the potato tuberization

Experiment variants	The number of tubers per 1 bush, pcs							
	Total	More than 80 g	25-80 g	Less than 25 g	Total	More than 80 g	25-80 g	Less than 25 g
	On the 45th day after germination				On the 60th day after germination			
Control, without treatment	6.1	1.2	3.8	1.1	7.0	2.6	2.2	2.2
BA-40.001%	8.0	2.0	5.0	1.0	8.6	4.0	3.1	1.5
BA-40.0001%	9.1	3.0	5.1	0.9	11.5	5.0	4.3	2.2
Extrasol 10% (ethanol)	6.5	1.3	4.0	1.2	8.3	2.5	3.0	2.8

**Table 4**  
The effect of seed pre-treatment with a new preparation on the yield of the “Aksor” potato variety

Experiment variants	Potato yield, t/ha	Gain to the control t/ha	%
Control, without treatment	22.7	-	-
BA-40.001%	27.0	4.3	18.9
BA-40.0001%	30.0	7.3	32.2
Extrasol 10% (ethanol)	25.0	2.3	10.1

On the basis of the conducted studies, it was found that diethyl-N-(1-ethynylcyclohex-1-yl)amidophosphate (6) (BA-4) demonstrated the pronounced properties of a plant growth stimulator. The optimal concentration for the preparation was 0.0001%. When treating the seeds of carrots, red beets and potato tubers with the specified preparation in the optimal doses, the plant seedlings appeared 2–4 days previously. The density of the plant standing (the field germination) increased by 21.4% when carrot seeds were treated with the preparation in the concentration of 0.0001%. The pre-sowing treatment of red beet seeds with the preparation in the concentration of 0.0001% increased the plant density by 37.5%. The studied preparation had a positive effect on the process of potato tuberization. At the first determination term (on the 45th day after germination), there were 9.1 pcs of tubers per 1 bush in the variant with the preparation in the concentration of 0.0001%; at the second determination term (on the 60th day after germination) there were 11.5 pcs of tubers in the variant with the similar concentration. The field tests showed that the plants grown from seeds and tubers, previously soaked in the solutions of the tested synthetic preparation, were growing and de-

veloping better, which ultimately led to an increase in vegetable crop yields. Thus, the use of the preparation in the optimal concentration of 0.0001% led to an increase in the yield of carrots by 5.0 t/ha (22.7%), of red beets by 6.3 t/ha (24.2%), and of potatoes by 7.3 t/ha (32.2%) [17].

#### 4. Conclusions

Dialkyl-N-(1-ethynylcyclohexan-1-yl)amidophosphates were isolated and characterized by phosphorylation of 1-amino-1-ethynylcyclohexane with dimethyl-, diethyl- and di( $\beta$ -chloroethyl) phosphites in high yields. Synthesis was carried out in a microwave reactor (MAS-II Plus MW) using microwave irradiation of the reaction mixture (MW 102 W, 115 °C) in  $\text{CCl}_4$  excess at an equimolar ratio of reagents, triethylamine was used as an HCl acceptor, the synthesis time was 3–5 min. The composition and structure of the obtained compounds were proved by elemental analysis, IR,  $^1\text{H}$ ,  $^{13}\text{C}$ ,  $^{31}\text{P}$  NMR spectroscopy, and X-ray diffraction analysis (XRD). The biological tests carried out in laboratory and field conditions allowed identifying diethyl-N-(1-ethynylcyclohexan-1-yl)amidophosphate among the synthesized compounds, which has a high growth-regulating effect on the growth, development, and yield of crops, protected by Invention Patent of the Republic of Kazakhstan.

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