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NEW *N*-BENZYLPIPERIDONE DERIVATIVES: SYNTHESIS AND PLANT GROWTH-STIMULATING ACTIVITY

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Abstract. *Introduction.* Given their broad range of biological activities and potential for further structural modification, piperidine derivatives, particularly *N*-benzylpiperidones, have attracted considerable attention. Because of their easily accessible starting materials and relatively simple synthesis, these compounds are particularly attractive because they facilitate the effective design and development of novel molecules with specific physicochemical and biological characteristics. *The objective of this study* is to synthesize a new series of benzylpiperidone derivatives, generate more complex nitrogen-containing heterocycles through structural modification, and evaluate their plant growth-stimulating activity. *Results and discussion.* *N*-benzylpiperidin-4-one was reacted with 1-(3-methoxypropyl)amine and paraformaldehyde to yield 3-benzyl-7-(3-methoxypropyl)-3,7-diazabicyclo[3.3.1]nonan-9-one. The resulting ketone was converted to the corresponding oxime with a 76% yield under oximation conditions. Subsequent acylation of the oxime with benzoyl chloride produced *O*-benzoyloxime in 65% yield. At a concentration of 0.001%, the complex (KhZR-107) was evaluated for its impact on the germination, growth, and development of soybean (variety Zhansaya) and wheat (variety Kazakhstan-10) seedlings. *Conclusion.* Treatment with KhZR-107 improved wheat performance, raising germination from 90% to 100%, increasing germination energy from 82.5% to 95%, and promoting taller seedlings, all without compromising seed sanitary quality. In soybean, germination rates remained unchanged, but the seedlings appeared slightly more uniform, suggesting subtle benefits in early development.

Keywords: *N*-benzylpiperidone, diazabicyclononanone, β-cyclodextrin inclusion complex, plant growth stimulation.

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1. Introduction

Heterocyclic compounds, particularly nitrogen-containing systems, are widely distributed in natural products and pharmaceutical agents [1]. Owing to their pronounced physiological properties and key roles in biological processes,

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nitrogen heterocycles occupy a central position in medicinal and agrochemical research [2]. Among them, piperidine-containing compounds represent one of the most important structural motifs in modern drug design. The high prevalence of the piperidine ring in approved drugs is attributed to its synthetic accessibility, conformational adaptability, and favorable pharmacokinetic characteristics [3,4].

Sustained interest in piperidine derivatives is largely associated with the availability of diverse starting materials and well-developed synthetic methodologies, which enable systematic structural modification. In particular, the introduction of benzyl substituents allows fine tuning of lipophilicity, steric environment, and intermolecular interactions, parameters that directly influence biological activity and target affinity [5,6].

At the same time, analysis of the available literature indicates that most investigations of *N*-benzylpiperidone derivatives have been primarily focused on medicinal applications or on the development of synthetic approaches. Reports addressing their potential agrobiological activity remain limited and fragmented. In particular, systematic studies correlating structural modifications of the benzylpiperidone scaffold with growth-regulating effects in plants are scarce. Furthermore, the transformation of *N*-benzylpiperidones into more structurally complex nitrogen-containing heterocycles and the evaluation of their growth-stimulating properties have not been comprehensively explored [7-9].

Plant growth regulators are an essential component of modern crop production technologies [10]. Even when applied in small doses, they influence plant metabolism, significantly affecting growth, development, and yield, and are regarded as environmentally friendly and cost-effective tools for enhancing crop productivity and realizing the biological potential of plants. Therefore, studying the effects of next-generation growth regulators on the yield and grain quality of spring wheat under specific soil and climatic conditions remains highly relevant [11-13]. However, despite the established pharmacological relevance of this class of compounds, significant gaps persist in understanding their structure–activity relationships in the context of plant growth regulation.

Although *N*-(4-substituted benzyl, phenyl, and imidazolyl)piperidones have shown moderate plant growth-stimulating activity [14,15], the combination of a 3-methoxypropyl group with *N*-(4-substituted benzyl)piperidone has not been investigated. Here, we report a series of novel 3-benzyl-7-(3-methoxypropyl)-3,7-diazabicyclo[3.3.1]nonan-9-one derivatives, whose structures were confirmed by NMR, IR spectroscopy, and elemental analysis. Preliminary biological evaluation demonstrates that the *O*-benzoyloxime derivative significantly improves wheat performance, increasing germination from 90% to 100%, raising germination energy from 82.5% to 95%, and promoting taller seedlings.

2. Experimental part

Chemical Part

Reaction progress was monitored by thin-layer chromatography employing aluminum oxide with second-degree activity. Infrared spectra were recorded on a

Nicolet 5700 FT-IR spectrometer. ^{1}H and ^{13}C NMR spectra were recorded on a JEOL JNM-ECA 400 spectrometer at frequencies of 399.78 and 100.53 MHz, respectively, using $CDCl_3$ as the solvent. Syntheses sensitive to oxygen or moisture were conducted under an inert gas atmosphere with dry solvents.

The synthesis of 3-benzyl-7-(3-methoxypropyl)-3,7-diazabicyclo[3.3.1]nonan-9-one and its derivatives followed procedures previously described [16].

3-Benzyl-7-(3-methoxypropyl)-3,7-diazabicyclo[3.3.1]nonan-9-one ***(2)****.* Yellow oil; 82%. Anal. calcd. for $C_{18}H_{26}N_2O_2$: C 71.49; H 8.67; N 9.26; Found: C 71.20; H 8.73. IR (KBr) (ν_{max}/ cm^{-1}): 1735 (C=O), 1118 (C-O-C). ^{1}H NMR (400 MHz, $CDCl_3$), δ, ppm (*J*, Hz): 1.66, 2.33 (H-3,7); 1.65, 1.68, 1.71, 2.40 (H-2,4,6,8); 2.44 (H-10); 2.52 (H-11); 2.74 (H-12); 2.75 (H-13); 2.78 (H-15); 3.49 (H-16); 7.20-7.30 (H-18,19,20,21,22). ^{13}C NMR (101 MHz, $CDCl_3$), δ, ppm (*J*, Hz): 57.23 (C-3,7); 54.34, 61.11 (C-2,4,6,8); 214.5 (C-9); 52.98 (C-11); 27.67 (C-12); 70.9 (C-13); 58.5 (C-15); 62.09 (C-16); 137.5 (C-17); 129.59 (C-18, 22); 128.48 (C-19,21); 127.03 (C-20).

Oxime of 3-benzyl-7-(3-methoxypropyl)-3,7-diazabicyclo[3.3.1]nonan-9-one ***(3)****.* Yellow oil; 76%. Anal. calcd. for $C_{18}H_{27}N_3O_2$: C 68.11; H 8.57; N 13.24; Found: C 68.06; H 8.43. IR (KBr) (ν_{max}/ cm^{-1}): 3222 (OH), 1671 (C=N). ^{1}H NMR (400 MHz, $CDCl_3$), δ, ppm (*J*, Hz): 1.71, 1.71 (H-3,7); 2.26, 2.82, 2.186 (H-2,4,6,8); 6.93 (H-11); 2.75 (H-12); 1.73 (H-13); 3.42 (H-14); 3.32 (H-16); 7.12-7.49 (H-19, 20, 21, 22, 23). ^{13}C NMR (101 MHz, $CDCl_3$), δ, ppm (*J*, Hz): 30.23 (C-3); 36.84 (C-7); 56.67, 57.16 (C-2,8); 58.06, 58.42 (C-4,6); 161.52 (C-9), 27.18 (C-13); 54.37 (C-12); 58.74 (C-16); 71.21 (C-14); 61.69 (C-17); 138.51 (C-18); 128.99 (C-19,23);127.09 (C-21); 128.42 (C-20,22).

O-Benzoyloxime of 3-benzyl-7-(3-methoxypropyl)-3,7-diazabicyclo[3.3.1]nonan-9-one ***(4)****.* Yellow oil; 65%. Anal. calcd. for $C_{25}H_{31}N_3O_3$: 71.23; H 7.41; N 9.97; Found: C 71.42; H 7.21. IR (KBr) (ν_{max}/ cm^{-1}): 1742 (C=O), 1637 (C=N). ^{1}H NMR (400 MHz, $CDCl_3$), δ, ppm (*J*, Hz): 2.8 (H-3,7); 2.3 (H-2,4,6,8); 3.5 (H-14); 7.1-7.4 (H-16, 17, 18, 19, 20); 2.5 (H-21); 1.7 (H-22); 3.4 (H-23); 3.3 (H-25); 7.6-8.0 (H-27, 28, 29, 30, 31). ^{13}C NMR (101 MHz, $CDCl_3$), δ, ppm (*J*, Hz): 38.09 (C-3); 41.09 (C-7); 60.57 (C-2,8); 59.43 (C-4,6); 168.99 (C-9); 158.91 (C-12); 62.04 (C-14); 138.86 (C-15); 127.03-132.12 (C-16,20,27,28,30,31); 27.67 (C-22); 70.49 (C-23); 58.5 (C-25); 133.35 (C-26).

Inclusion complex of O-benzoyloxime with β-cyclodextrin (CD) ***(5)****.* Wight power decomposed in 200 ^{o}C. Anal. calcd. for $C_{60}H_{96}N_2O_{37}$: C 51.17; H 6.49; N 2.70; Found: C 51.05; H 6.24. ^{1}H NMR (400 MHz, $CDCl_3$), δ, ppm (*J*, Hz): 0.98, 1.05 (H-3,7); 0.96, 1.00, 1.04, 1.83 (H-2,4,6,8); 3.26 (H-14); 3.30-3.44 (H-16,17,18,19,20); 3.45 (H-21); 3.46 (H-22); 3.6 (H-23); 4.84 (H-25); 7.2-7.27 (H-27,28,29,30,31); 7.29-7.89 (H-32,33,34,35,36,37,38).

Biological part

Model samples of wheat and soybean were used to evaluate the effects of stimulants, with the commercial preparation Baikal EM-1 serving as a reference. Water served as the medium for seed germination. For the germination test, four

replicates of 100 seeds each were selected from the main seed lot (combined sample). In this study, 10 seeds were sown in each of four replicates, corresponding to 100% seeding. Germination energy was assessed on day 3, and germination rate on day 7. For germination energy (after 3 days for wheat and soybean), normally germinated seeds were counted and removed, as were rotten seeds. Ungerminated and abnormally germinated seeds remained for further observation. For germination rate (after 7 days for wheat and soybean), all seeds were classified as normally germinated, abnormally germinated, swollen, hard (for legumes), or rotten, and the number of seeds in each group was recorded. The germination percentage was calculated for each sample, and the reliability of the results was verified. Both germination percentage and germination energy were determined. Spring wheat variety "Kazakhstan-10" and soybean variety "Zhansaya" from the collection of the Institute of Plant Biology and Biotechnology were treated during seed germination, seedling growth, and development for 24 hours according to standard protocols. Laboratory experiments were performed to assess the effects of stimulants on germination energy, germination rate, and germination intensity of wheat and soybean seeds.

The complex was evaluated at a concentration of 0.001% for its effects on germination, growth, and early development of wheat (variety "Kazakhstan-10") and soybean (variety "Zhansaya") seedlings under controlled laboratory conditions. A 0.001% solution of Baikal EM-1 served as a comparative reference. All experiments were conducted in triplicate, with at least 100 seeds per replicate.

Methodology

Seed germination and growth measurements

Seeds were sterilized in 1% sodium hypochlorite for 5 min, rinsed three times with distilled water, and placed on moistened filter paper in Petri dishes. Germination was monitored daily, and germination energy (percentage of seeds germinated within 3 days) and final germination (%) were calculated. Seedling height was measured at 7 days post-germination using a digital calliper, recording mean ± SD for each replicate.

Microbial contamination assessment

Microflora presence was recorded qualitatively: "-" none, "+" low, "++" moderate, "+++" high contamination.

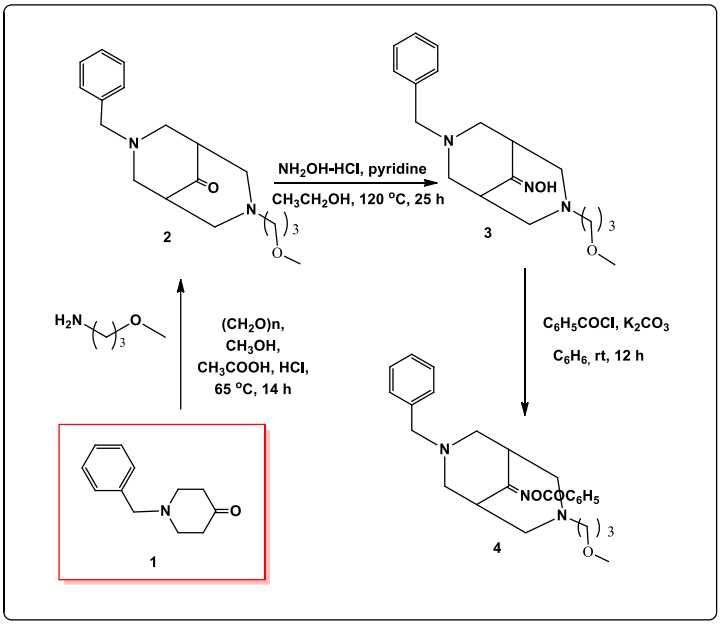
Statistical analysis

Data are expressed as mean ± standard deviation (SD). Differences between control and treated groups were assessed using one-way ANOVA, followed by Tukey's post hoc test. Differences were considered statistically significant at $p < 0.05$. Graphical representation includes error bars (SD) and asterisks for statistically significant differences.

3. Results and discussion

Cyclization of 1-benzylpiperidin-4-one (**1**) with 1-(3-methoxypropyl)amine and paraformaldehyde via a Mannich condensation in an acetic acid-methanol mixture at 65 °C for 14 h afforded the bicyclic ketone (**2**) in 82% yield. The new

bicyclic ketone (**2**) was isolated by column chromatography (Al_2O_3, eluent: benzene/ *i*-propanol – 1:6), and the reaction product is a viscous oil.



The IR spectrum of 3-benzyl-7-(3-methoxypropyl)-3,7-diazabicyclo[3.3.1]nonan-9-one (**2**) displayed an intense absorption band at 1735 cm^{-1}, characteristic of the stretching vibrations of the ketone carbonyl group at the C9 position. Additionally, the band at 1118 cm^{-1} indicated the presence of a simple ether C–O–C linkage associated with the methoxypropyl substituent.

The ^{1}H NMR spectrum showed signals for the protons of the bicyclic framework in the range 1.65-2.40 ppm (H3,7 and H2,4,6,8). The methoxypropyl fragment was identified by signals at 2.52 ppm (H11), 2.74 ppm (H12), 2.75 ppm (H13), and 2.78 ppm (H15). Aromatic protons of the benzyl substituent resonate in the region 7.12-7.35 ppm, confirming the presence of a phenyl ring. In the ^{13}C NMR spectrum, the most downfield signal at 214.5 ppm corresponds to the carbonyl carbon C9. Signals for the bicyclic skeleton carbons C3 and C7 were observed at 57.23 ppm, while resonances for C2, C4, C6, and C8 appear in the range 54.3-61.1 ppm, which is characteristic of a 3,7-diazabicyclic system. Signals for the *N*-substituents (C10-C14) and the aromatic carbons of the benzyl fragment (127.03-137.5 ppm) were consistent with the proposed structure.

The structure of the compound (**2**) was additionally confirmed by two-dimensional NMR spectroscopy using COSY (^{1}H-^{1}H), HMQC (^{1}H-^{13}C), and HMBC (^{1}H-^{13}C) techniques, which enable the identification of homo- and heteronuclear spin-spin interactions. The observed ^{1}H-^{1}H COSY and ^{1}H-^{13}C HMQC correlations in the molecule are shown schematically.

In the ^{1}H-^{1}H COSY spectra of the compound, spin–spin correlations through three bonds were observed between protons of neighboring methylene-methylene, methyl-methine, and methane-methine groups: H12-H11 (δ 1.87, 2.61 and 2.61, 1.87), H16-H15 (δ 1.31, 3.59 and 3.59, 1.32), H12-H13 (δ 1.86, 3.60 and 3.60, 1.86), and H3,7-H4$_{eq}$,6$_{eq}$ (δ 2.95, 3.16 and 3.16, 2.95 ppm).

Heteronuclear one-bond ^{1}H-^{13}C correlations were established by HMQC spectroscopy for the following proton-carbon pairs present in the compound: H16-C16 (δ 1.33, 15.53), H12–C12 (δ 1.83, 27.84), H11-C11 (δ 2.71, 47.05), H2ax,8ax, 2$_{eq}$,6$_{eq}$-C2,8 (δ 2.61, 53.81), H4$_{ax}$,6$_{ax}$-C4,6 (δ 2.94, 58.54), H4$_{eq}$,6$_{eq}$C4,6 (δ 3.18, 58.58), H15-C15 (δ 3.61, 66.60), H13-C13 (δ 3.60, 68.68), H17-C17 (δ 3.70, 61.51), H21-C21 (δ 7.43, 126.88), and H19,23,20,22-C19,23,20,22 (δ 7.47, 128.60 ppm).

Long-range heteronuclear ^{1}H-^{13}C correlations through two or more bonds were identified by HMBC spectroscopy for the following pairs: H16-C15 (δ 1.31, 66.53), H12-C2,8 (δ 1.85, 53.81), H12-C13 (δ 1.85, 68.70), H17-C4,6 (δ 3.67, 58.49), H17-C19,23 (δ 3.67, 129.04), and H17-C18 (δ 3.67, 138.71 ppm).

Bicyclic ketone (**2**) was heated with a strong oximation agent in an alcoholic medium at 120 °C for 25 h, affording the corresponding oxime (**3**) in 76% yield. The oxime was purified by column chromatography on Al_2O_3 (eluent: benzene/isopropanol, 1:20), and the product was obtained as a viscous oil.

In the IR spectrum of oxime (3), the characteristic C=O absorption band of the bispidinone fragment disappeared. A broad band at 3222 cm^{-1}, corresponding to the stretching vibrations of the oxime hydroxyl group (C=NOH), and an intense band at 1671 cm^{-1}, attributed to the C=N stretching vibration, were observed. These features confirmed the transformation of the carbonyl group of the initial ketone into an oxime.

In the ^{1}H NMR spectrum of the compound, the methylene protons H-13,13 of the methoxypropyl fragment appeared as a two-proton multiplet at δ 1.71-1.76 ppm. The methylene protons H-12,12 of this fragment were observed as a two-proton broadened singlet at δ 1.89 ppm. The methylene protons H-13,12, H-14,14, and H-14,14 of the methoxypropyl fragment resonated as two-proton multiplets at δ 2.40-2.50, 3.41-3.45, and 3.49-3.76 ppm, respectively. The methyl protons H-16,16,16 of the methoxypropyl fragment appeared as a three-proton singlet at δ 3.32 ppm.

The diazabicyclohydroxyimino protons H-2$_{ax}$,8$_{ax}$ were observed as a two-proton multiplet at δ 2.45-2.62 ppm. The diazabicyclohydroxyimino protons H-2$_{eq}$,8$_{eq}$ and H-4$_{ax}$,6$_{ax}$,4$_{eq}$,6$_{eq}$ appeared as a six-proton multiplet at δ 2.75-2.78 ppm. The diazabicyclohydroxyimino protons H-7 and H-3 were recorded as a one-proton multiplet and a singlet at δ 2.66-2.71 and 3.64 ppm, respectively. The hydroxyl proton H-11 resonated together with the aromatic protons H-19-23 as a six-proton multiplet at δ 7.22-7.34 ppm.

In the ^{13}C NMR spectrum, signals of the carbon atoms of the methoxypropyl fragment were observed at δ 27.18 (C-13), 54.37 (C-12), 58.74 (C-16), and 71.21 ppm (C-14). Carbon atoms of the diazabicyclohydroxyimino fragment resonated

at δ 30.23 (C-3), 36.84 (C-7), 56.67 and 57.16 (C-2,8), 58.06 and 58.42 (C-4,6), and 161.52 ppm (C-9). The methylene carbon atom C-17 appeared at δ 61.69 ppm. Aromatic carbon atoms were detected at δ 127.09 (C-21), 128.42 (C-20,22), 128.99 (C-19,23), and 138.51 ppm (C-18).

The structure of the compound (**3**) was additionally confirmed by two-dimensional NMR spectroscopy using COSY (^{1}H-^{1}H), HMQC (^{1}H-^{13}C), and HMBC (^{1}H-^{13}C) techniques, which allow the identification of homo- and heteronuclear spin–spin interactions. The observed ^{1}H-^{1}H COSY and ^{1}H-^{13}C HMQC correlations in the molecule are shown schematically.

In the ^{1}H-^{1}H COSY spectra, three-bond spin-spin correlations were observed between protons of neighboring methylene-methylene, methyl-methine, and methine–methine groups: H13-H12 (δ 1.73, 2.42 and 2.42, 1.73), H13-H14 (δ 1.73, 3.40 and 3.40, 1.73), and H-2_{ax},8_{ax}-H-7 (δ 2.52, 2.77 and 2.77, 2.52 ppm).

One-bond heteronuclear ^{1}H-^{13}C correlations were established by HMQC spectroscopy for the following proton–carbon pairs: H16-C16 (δ 3.30, 58.72), H12-C12 (δ 2.41, 54.29), H13-C13 (δ 1.74, 27.16), H-2_{ax},8_{ax},2_{eq},6_{eq}-C2,8 (δ 2.77, 56.54), H-4_{ax},6_{ax},4_{eq},6_{eq}-C4,6 (δ 2.76, 58.50), H-7-C7 (δ 2.61, 36.88), H-3-C3 (δ 3.63, 30.28), H-14-C14 (δ 3.40, 71.27), H-17-C17 (δ 3.49, 61.69), and H-19,23,20,22-C19,23,20,22 (δ 7.27, 128.60 ppm). Long-range heteronuclear ^{1}H-^{13}C correlations through two or more bonds were identified by HMBC spectroscopy for the following pairs: H13-C12 (δ 1.73, 54.76), H13-C14 (δ 1.73, 71.12); H12-C13 (δ 2.41, 27.09), H12-C2,8 (δ 2.41, 56.17), H12-C4,6 (δ 2.41, 58.42), H12-C14 (δ 2.41, 71.27); H14-C13 (δ 3.40, 27.15), H14-C12 (δ 3.40, 53.92); H16-C14 (δ 3.30, 71.45); H17-C2,8 (δ 3.49, 56.83), H17-C4,6 (δ 3.49, 58.86), H17-C20,22 (δ 3.49, 129.25), and H17, C18 (δ 3.49, 138.92 ppm).

Acylation of oxime (**3**) with benzoyl chloride in absolute benzene at room temperature for 12 h afforded the corresponding *O*-benzoyloxime (**4**) in 65% yield. The product was purified by column chromatography on Al_2O_3 using benzene/isopropanol (7:1) as the eluent. The IR spectrum of compound (**4**) exhibits an intense absorption band at 1742 cm^{-1}, corresponding to the ester carbonyl group of the benzoyl fragment, as well as a band at 1637 cm^{-1} characteristic of the C=N bond of the oxime moiety, confirming the formation of the *O*-benzoylated derivative.

A crystalline inclusion complex (**5**) of compound (**4**) with β-CD was prepared in an equimolar ratio. The resulting complex (**5**), designated KhZR-107, exhibits high thermal stability, decomposing above 240 °C.

The inclusion complex of *O*-benzoylated derivative with β-CD (KhZR-107) was studied at a concentration of 0.001% for its effects on germination, growth, and development of wheat seedlings (variety Kazakhstan-10) and soybean seedlings (variety Zhansaya) under laboratory conditions. For comparison, a solution of Baikal EM-1 at 0.001% was used. The results of the study are presented in Tables 1 and 2 and Figures 1 and 2.

Table 1 - Influence of KhZR-107 on germination and growth of wheat seeds under controlled laboratory conditions

Treatment	Germination, %	Germination energy, %	Mean height, cm	Contamination with microflora
Control	90 ± 2	82.5 ± 1.5	9.5 ± 0.4	-
KhZR-107	100 ± 0	95.0 ± 1.2*	11.0 ± 0.5*	-
*Significant difference compared to control ($p < 0.05$)				

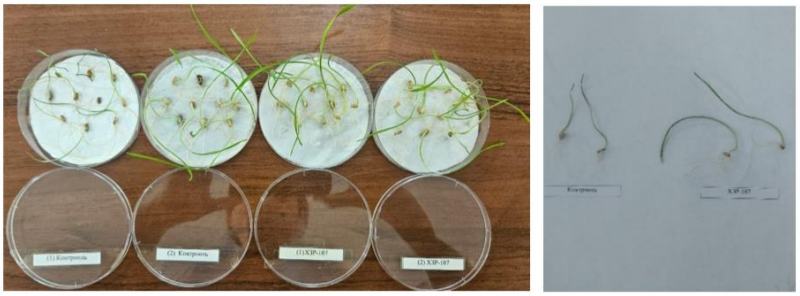


Figure 1 - Influence of KhZR-107 on germination, growth, and development of Kazakhstan-10 wheat seedlings under laboratory conditions.

As shown in Table 1, treatment with KhZR-107 produced a pronounced stimulatory effect on wheat seeds. Laboratory germination increased from 90% in the control to 100%, while germination energy rose from 82.5% to 95.0%. In addition, treated seedlings exhibited more vigorous early growth, as indicated by a mean shoot height increase from 9.5 cm to 11.0 cm. The absence of visible microflora contamination in both control and treated variants indicates that the preparation did not negatively affect seed sanitary status. The simultaneous improvement of germination energy and seedling height suggests that the complex not only accelerated seed awakening but also supported subsequent metabolic activity during early ontogenesis.

Table 2 - Effect of KhZR-107 on germination and seedling development of Zhansaya soybean under laboratory conditions

Treatment	Germination rate, %	Seed germination energy, %	Contamination with microflora
Control	50 ± 3	45.0 ± 2.0	+++
KhZR-107	50 ± 2	45.0 ± 1.8	+++

In contrast to wheat, soybean seeds showed no quantitative changes in germination rate or germination energy following treatment with KhZR-107 (Table 2). Both indicators remained at the control level (50% and 45.0%, respectively). Microflora contamination (+++) was observed in both experimental and control groups, indicating that the preparation did not exert a protective or inhibitory effect on associated microorganisms under the tested conditions.

Nevertheless, visual observations in the moist chamber indicated more uniform seedling development, suggesting that the preparation may influence post-germination physiological processes rather than the initial germination stage in soybean.

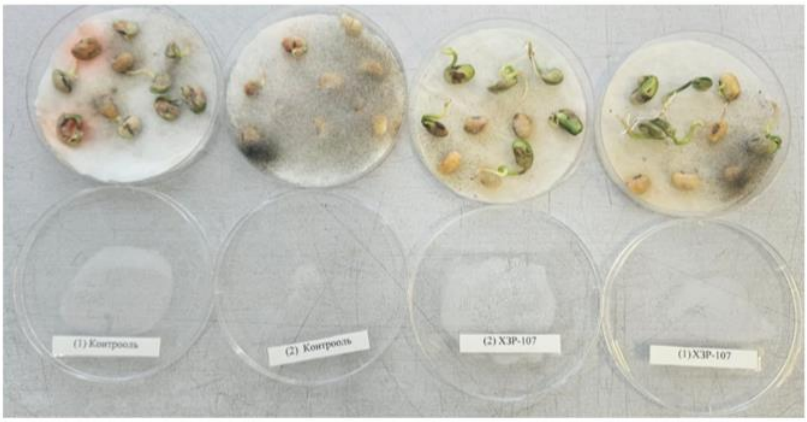


Figure 2 - Effect of KhZR-107 on germination and early seedling development of Zhansaya soybean under laboratory conditions.

Possible Mechanism of Growth-Stimulating Action of KhZR-107

The growth-promoting effect of KhZR-107 in wheat may be attributed to enhanced bioavailability of the *O*-benzoylated oxime derivative resulting from its inclusion into β-cyclodextrin.

Such complexation [17,18] is known to improve solubility and facilitate penetration of the active compound into the seed during imbibition, thereby enabling more efficient interaction with metabolically active tissues. The observed increase in germination energy [19] suggests stimulation of early metabolic processes, particularly activation of enzymatic systems involved in reserve mobilization. Enhanced amylolytic activity and accelerated nutrient supply to the embryo may account for both faster germination and increased seedling height.

Furthermore, oxime-containing compounds may affect redox homeostasis. Controlled modulation of reactive oxygen species [20] during early ontogenesis could promote synchronized germination and stimulate cell division. The absence of significant quantitative effects in soybean indicates species-specific sensitivity, possibly related to differences in seed composition and metabolic pathways. Nevertheless, improved seedling uniformity suggests that KhZR-107 may influence post-germination physiological processes.

Overall, the findings indicate that KhZR-107 functions as a mild metabolic activator rather than a classical phytohormone analogue [21], enhancing early growth without exhibiting phytotoxic effects.

4. Conclusion

A new series of 3-benzyl-7-(3-methoxypropyl)-3,7-diazabicyclo[3.3.1]nonan-9-one derivatives was synthesized from 1-benzylpiperidin-4-one and structurally confirmed by IR, $^{1}H/^{13}C$ NMR, and 2D experiments. Incorporation of the *O*-benzoylated oxime into a β-CD inclusion complex (KhZR-107) enhanced biological activity. In wheat (Kazakhstan-10), KhZR-107 increased germination from 90% to 100%, germination energy from 82.5% to 95%, and shoot height from 9.5 to 11.0 cm, without affecting seed sanitary quality. In soybean (Zhansaya), germination remained unchanged, although seedling development was slightly more uniform. These results highlight KhZR-107 as a promising cereal growth stimulator, particularly for wheat, while further greenhouse and field studies are needed to optimize its application and confirm microbiological stability.

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Conflict of Interest: The authors declare that there is no conflict of interest regarding the data presented in this article.

ЖАҢА *N*-БЕНЗИЛПИПЕРИДОН ТУЫНДЫЛАРЫ: СИНТЕЗІ ЖӘНЕ ӨСІМДІК ӨСУІН ЫНТАЛАНДЫРУШЫ ӘСЕРІ

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Түйіндеме. *Кіріспе.* Пиперидин туындылары, әсіресе *N*-бензилпиперидондар, кең фармакологиялық әлеуетке ие және әрі қарай химиялық түрлендіру үшін перспективалы болып табылады. Оларға деген қызығушылық бастапқы реагенттердің қолжетімділігімен және салыстырмалы түрде қарапайым синтез жолдарымен байланысты, бұл берілген физика-химиялық және биологиялық қасиеттері бар жаңа қосылыстарды жобалауға мүмкіндік береді. Осы *жұмыстың мақсаты* - бензилпиперидон туындыларының жаңа қатарын синтездеу, құрылымдық модификациялау арқылы күрделірек азотқұрамды гетероциклдерді алу және олардың өсімдік өсуін ынталандыру белсенділігін зерттеу. *Нәтижелер және талқылау.* 1-Бензилпиперидин-4-он 1-(3-метоксипропил)аминмен және параформальдегидпен әрекеттесіп, 3-бензил-7-(3-метоксипропил)-3,7-диазабицикло[3.3.1]-нонан-9-он түзді. Кетон оксимациялау жағдайында 76% шығыммен сәйкес оксимге айналдырылды. Оксимді бензойлхлоридпен ацилдеу нәтижесінде 65% шығыммен *О*-бензоилоксим алынды. ХЗР-107 кешені 0,001% концентрацияда бидайдың (Қазақстан-10 сорты) және сояның (Жансая сорты) тұқымдарының өнуіне, өсуі мен дамуына әсері тұрғысынан зерттелді. *Қорытынды.* ХЗР-107 препаратымен өңдеу бидай өсімін жақсартты: өсу көрсеткіші 90%-дан 100%-ға дейін өсті, өсу энергиясы 82,5%-дан 95%-ға дейін артты, ал бұл дәндер биіктігінің артуына әкелгенмен, бұл ұрықтың санитарлық сапасына әсер етпеді. Соя тұқымында өсу көрсеткіштері өзгермеді, бірақ көшеттер сәл біркелкі болып көрінді, бұл ерте даму кезеңіндегі оң әсерлерді көрсетеді.

Түйінді сөздер: *N*-бензилпиперидон, диазабициклононанон, β-циклодекстриннің инклюзиялық кешені, өсімдіктердің өсуін ынталандыру.

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НОВЫЕ *N*-БЕНЗИЛПИПЕРИДОНОВЫЕ ПРОИЗВОДНЫЕ: СИНТЕЗ И РОСТСТИМУЛИРУЮЩАЯ АКТИВНОСТЬ РАСТЕНИЙ

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Резюме. *Введение.* Производные пиперидина, в частности *N*-бензилпиперидоны, проявляют широкий фармакологический потенциал и являются перспективными объектами для дальнейшей химической модификации. Интерес к ним обусловлен доступностью исходных веществ и относительной простотой синтеза, что позволяет конструировать новые соединения с заданными физико-химическими и биологическими свойствами. *Целью данной работы* является синтез новой серии производных бензилпиперидона, получение более сложных азотсодержащих гетероциклов путём структурной модификации и изучение их ростстимулирующей активности в отношении растений. *Результаты и обсуждение.* 1-Бензилпиперидин-4-он взаимодействовал с 1-(3-метоксипропил)амином и параформальдегидом с образованием 3-бензил-7-(3-метоксипропил)-3,7-диазабицикло[3.3.1]нонан-9-она. Кетон был превращён в соответствующий оксим с выходом 76% в условиях оксимации. Ацилирование оксима бензоилхлоридом привело к получению *O*-бензоилоксима с выходом 65%. Комплекс ХЗР-107 был исследован на влияние на прорастание, рост и развитие проростков пшеницы (сорт Казахстан-10) и сои (сорт Жансая) при концентрации 0,001%. *Заключение.* Обработка ХЗР-107 улучшила показатели пшеницы: всхожесть повысилась с 90% до 100%, энергия прорастания увеличилась с 82,5% до 95%, а рост сеянцев стал выше, при этом санитарное качество семян не пострадало. У сои показатели всхожести остались без изменений, однако сеянцы выглядели немного более равномерными, что указывает на умеренные положительные эффекты в раннем развитии.

Ключевые слова: *N*-бензилпиперидон, диазабициклононанон, комплекс включения β-циклодекстрина, стимулирование роста растений.

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