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Dynamics of germination of vegetable seeds when using dimethyl (1-hydroxy-1-phenylethyl) phosphanate as an accelerator

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ABSTRACT

This study examines the effects of dimethyl (1-hydroxy-1-phenylethyl) phosphonate as a germination accelerator on various vegetable seeds. Seed germination is a critical phase in plant growth, significantly influencing crop yield and quality. The primary objective was to determine the compound's efficacy in enhancing germination rates and vigor by monitoring key indicators such as germination percentage, speed, and seedling development. A range of concentrations was tested to identify optimal dosages and effects. Results indicated that dimethyl (1-hydroxy-1-phenylethyl) phosphonate, at specific concentrations, significantly improved germination speed and uniformity, with enhanced early growth metrics compared to untreated controls. The findings suggest that this compound may be an effective germination promoter in agricultural applications, potentially reducing germination time and improving crop establishment under diverse conditions.

Keywords: Plant, Stimulator, Succinic acid yield, Tomato, Growth.
Article type: Research Article.

INTRODUCTION

Implementation of the Sustainable Development Goals (UNESCO 2017), as a specialized institution, is entrusted to the education authorities in the region. In this regard, the coordination of activities is also implemented in implementing the global "Education-2030" agenda - the 4th goal is to ensure quality education and justice and encourage the use of all educational opportunities. It is important to organize a comfortable life for everyone, provide quality education, and prepare food resources. One of the people's requests for improving the quality of resources in implementing sustainable development goals is food quality - it is necessary to put it in a 12-target system (UNESCO 2017). The development of agro-industry through growth accelerators can contribute to the sustainable development of the food industry. Plant growth accelerators are known that can be used in crop production in the agro-industrial complex (Kolbinb *et al.* 2005; Muromshev *et al.* 1987). Heavy metal pollution of the environment had a great impact on Asimian agriculture. Storage of traces in environmental objects stretches voltammetry alkyls anaqtaudyn teoriyalyk needed azirlengen. Prospects for monitoring the use of noble and heavy metals in Kazakh artificial and mineral raw materials are shown (Musina *et al.* 2018). It is known that using phosphorus-containing compounds as activators of plant life processes is of practical importance. In phosphonpiperidols, the nature of the substitution of the nitrogen atom was found to have a significant effect on the activity of phosphorus-containing compounds in the piperidine series. Unsubstituted phosphonpiperidols are less active than N-alkyl equivalents (Nifantiev *et al.* 1971; Dzhiembaev *et al.* 2003). Pesticides, antidotes, seed treatments, and plant growth regulators based on bactericides, insecticides, acaricides, nematicides, and zoocides are known to be used in agriculture (Tverdyukov 1999; Chudinova *et al.* 2012). Some features of plant growth

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and development are regulated by auxin under the influence of a transcription activator. This study shows that SIARRI is a major leaf morphology and fruit development regulator. In addition, overexpressed plants provide new insights into tomato fruit ripening with auxin-related growth changes (Fahad *et al.* 2023). Agrochemicals such as pesticides and fertilizers are used in agriculture to improve plant growth and protection. Although initially intended to increase yields, they have been found to affect soil and water quality adversely. Using chemicals in agriculture significantly affects plants and food chains (Baitasheva *et al.* 2024). The disadvantage of using plant growth regulators is that their use usually requires consideration that each is intended to promote growth development and increase the yield of specific crops in appropriate amounts, timing, and application methods. At the same time, work on preparing seed material is being carried out unsatisfactorily. Due to financial difficulties, the cost of seed treatment was reduced to a minimum (Pesticides *et al.* 1995). The closest in technical dryness to the claimed object is heteroauxin, which is a sodium or potassium salt of β-indoleacetic acid (Melnikov *et al.* 1962). The main disadvantage of heteroauxin is its instability during storage (quickly darkens in the light), phytotoxicity, and low efficiency as a growth and productivity accelerator (Melnikov *et al.* 1995). This new substance has a positive effect on the ecophysiological indicators of plants. These parameters depend on environmental conditions. The ecophysiological study also includes various functional, physiological, biochemical, and biophysical aspects of trees for plant productivity. Determining the variability of the physiological functions of the studied species and their adaptation to environmental conditions, such as soil and water quality, is especially important for countries with arid climates, including Kazakhstan (Issayeva *et al.* 2022; Smanov *et al.* 2023; Amanbayeva *et al.* 2024; Ayana *et al.* 2024). The sorption capacity and field application of activated carbons (ACs) derived from plant residues for the remediation of oil-contaminated soils (Sabitov *et al.* 2024).

MATERIALS AND METHODS

The purpose of the invention is to expand the spectrum of action and the arsenal of agricultural plant growth accelerators and eliminate the above-mentioned disadvantages. The technical result is an increase in the yield of agricultural crops (cucumbers and tomatoes), their further growth and development, as well as a significant reduction in yield and toxicity. During the growing season, a biometric calculation was carried out on 20 typical plants according to the following indicators: plant height, number of leaves, and fruit weight. Productivity in field experiments was measured and considered separately for each plot. According to B. A. Dospekhov, a mathematical analysis of profitability data was carried out using the dispersion method (Dospehov *et al.* 2011). Changes in the morphological state of plants originating from treated seeds were observed (Mussina *et al.* 2018; Nurmahanova *et al.* 2024). The area of the census plot of cucumbers and tomatoes, 10 m^2, was repeated four times. In the experiments, phenological observations were carried out for each option, taking into account the timing of sowing, single and mass shoots, the appearance of 2-3 and 6-8 leaves (Uklyudova *et al.* 1978; Bryzgalov *et al.* 1982; Fedorov *et al*. 2003). Growing cucumbers and tomatoes occurred under drip irrigation conditions in greenhouse conditions (Kravtsova *et al.* 2000). Composting is one of the urban waste management techniques that aims to lessen the amount and weight of trash that needs to be removed, as well as the spread of flue and fat, resource recycling, and disposal costs (Syman *et al.* 2022). Work has been carried out to control the influence of a chemical substance that affects the growth and development of plants on the activity of using cucumbers and tomatoes as growth accelerators in the agro-industrial complex. Dimethyl (1-hydroxy-1-phenylethyl) phosphonate with the code AKKU-36 and the following formula was proposed as a growth stimulator for cucumbers and tomatoes for the technical result.

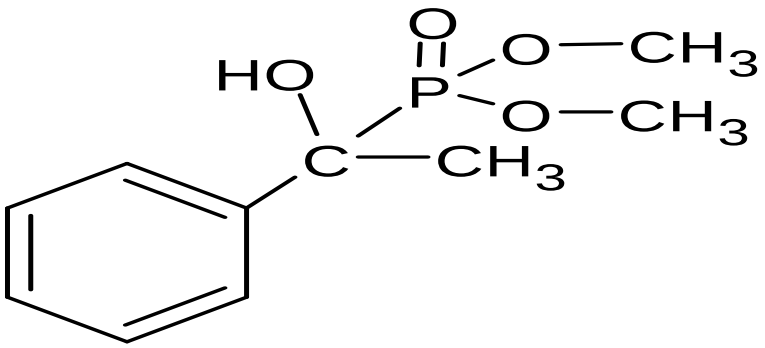

Fig. 1. The formula Dimethyl (1-hydroxy-1-phenylethyl) phosphonate with the code AKKU-36.

At low concentrations of dimethyl (1-hydroxy-1-phenylethyl) phosphanate (from now on referred to as the drug preparation AKKU-36; 0.001 and 0.0001%), pre-sowing treatment of seed material increases germination. Treatment with a drug (preparation) conventionally called AKKU-36 at 0.001 and 0.0001%, compared to the control, increases the germination energy of cucumber seeds by 26.2 and 30.0%. At 0.001 and 0.0001%, the germination of cucumber seeds increases by 13.0 and 25.6% compared to the control. Treatment of cucumber seeds (0.002%) with a solution of succinic acid increased germination energy and germination by 20.0 and 14.0%, respectively, compared to the control. The study of the drug's (preparation) effect on the initial growth rate of cucumber seedlings was carried out 30 days after planting the seedlings in greenhouse conditions. From the data given in Table 4, it follows that the height of the seedling grown from seeds treated with AKKU-36 at 0.001% was higher compared to the control on the 10^{th}, 20^{th}, and 30^{th} days of recording (11.5, 20, and 18.8 cm); while at 0.0001% were 15.4, 25.3 and 26.8 cm, respectively. Using the standard leads to a slight increase in the height of cucumber seedlings. Treatment of cucumber tubers with AKKU-36 at 0.001% showed that awakened fruits increased the number of tubers by 20.0% compared to the control. Cucumber plant pruning was treated the same as all treatments. Treatment of tubers with AKKU-36 at 0.0001% increased the number of awakened fruit tubers by 25.0% compared to the control. Treatment of tomato seeds in a solution of AKKU-36 at 0.001% increases the energy of seed germination by 17.4%, and germination by 10.1%; while at 0.0001% by 36.8 and 20.8%, respectively. The succinic acid standard (0.002%) increased germination energy by 14.8% and germination by 8.8%. Treating tomato seeds before sowing increases plant density.

The data in Table 10 show that treating tomato seeds with AKKU-36 at 0.001% increases plant density by 25.6% and 0.0001% by 32.5%. Soaking in a solution of succinic acid (0.002%) increased the standing density by 13.8%. When tomato seeds were treated with AKKU-36 at 0.0001%, the maximum increase in control was obtained and amounted to 6.3 ton ha^{-1}, or 21.2% (Dzhienbaev *et al*. 2023). These indicators of vegetables vary depending on their active substances (Ramazanova *et al.* 2023).

For the first time, Kazakh National Women's Pedagogical University JSC, under the code AKKU-36, proposed dimethyl (1-hydroxy-1-phenylethyl) phosphonate as a growth accelerator for vegetable crops, specifically cucumbers and tomatoes (Melnikov *et al.* 1962). This compound is highly effective for increasing and improving the yield of agricultural crops. Compared to the prototype with the target, the proposed compound is less toxic under experimental conditions, practically safe for the environment, and highly effective for increasing crop yields and improving their quality.

Experiment site

The research work was carried out based on the project "IP202407: “Investigation of the direction of solving world problems by integrating SDGs into the educational process” in the laboratory of the Chemistry and Biology Research Center in the "Institute of Natural Sciences" as well as in the laboratory of the Department of Biology and in the greenhouse in the field of the experimental greenhouse adjacent to the Lyceum of the Suyinbay School No. 143.

RESULTS AND DISCUSSION

Experiment 1.1. Study the drug's (preparation) effect on the germination energy and germination of cucumber seeds

The results of laboratory studies showed that treating seeds with a conventional preparation called AKKU-36 at the concentrations of 0.001 and 0.0001%, compared to the control, increases the germination energy of cucumber seeds by 26.2 and 30.0%. At 0.001 and 0.0001% of AKKU-36, the germination of cucumber seeds increases by 13.0 and 25.6% compared to the control. Treatment of cucumber seeds (0.002%) with a solution of succinic acid increases germination energy and germination by 20.0 and 14.0%, respectively, compared to the control (Table 1; Fig. 1).

Experiment 1.2. Study the drug's (preparation) effect on germination energy and germination of tomato seeds

According to the data given in Table 2, treatment of tomato seeds in a solution of AKKU-36 at 0.001% increases the energy of seed germination by 17.4%, and germination by 10.1%; while at 0.0001% by 36.8 and 20.8%, respectively. The succinic acid standard (0.002%) increases germination energy by 14.8% and germination by 8.8%.

Fig. 1. The growth period of cucumbers and tomatoes under laboratory conditions.

Table 1. Effect of the new drug (preparation) on germination energy and germination of cucumber seeds.

Types of Experiment	Cucumber	
	Germination energy (%)	germination (%)
Control, without treatment	50.0	72.0
AKKU-36 0.01%	30.0	27.0
AKKU-36 0.001%	76.2	85.0
AKKU-36 0.0001%	80.0	97.0
Succinic acid solution (0.002%) (standard)	70.0	84.0

Table 2. Effect of the new drug (preparation) on germination energy and germination of tomato seeds.

Types of experiment	Tomatoes	
	Germination energy (%)	Germination (%)
Control, without treatment	53.2	76.2
AKKU-36 0.01%	65.5	70
AKKU-36 0.001%	78.6	93.0
AKKU-36 0.0001%	87.8	96.0
Succinic acid solution (0.002%; standard)	65.0	88.0

Experiment 2. Effect of AKKU-36 during pre-sowing treatment of cucumber seeds on plant growth, leaf development, and yield

The results of phenological observations show that in laboratory conditions, cucumber fruit seeds germinated 3 and 6 days earlier than during observation in the experiment, impregnated with AKKU-36 in solutions at 0.001% and 0.0001% respectively. The seeds appeared 4 days earlier than the Control. Experiment seedlings treated with succinic acid when treating cucumber leaves with succinic acid solution (standard). When treated with the drug (preparation) at 0.001%, the phase of 2-4 and 6-8 true leaves appeared 3 days earlier, while treated at 0.0001%, up to 8 days (Table 3). Treating seeds with the above preparation (drug) in optimal concentration before sowing increases the yield of cucumber fruits.

Table 3. Intensity of emergence of shoots and phases of development of cucumber fruits under the influence of treatment with AKKU-36.

Types of Experiment	Seedling		2-4 leaf phase	6-8 leaf phase
	Primary	Massive		
Control, without treatment	08.01	12.01	18.12	07.01
AKKU-36 0.001%	05.01	10.01	15.12	05.01
AKKU-36 0.0001%	02.01	06.01	10.12	28.12
Succinic acid solution (0.002%; standard)	04.01	10.01	15.12	03.01

Experiment 2.1. Study the effect of the drug (preparation) on the growth rate of cucumber seedlings (in greenhouse experiment)

A study of the drug's (preparation) effect on the growth rate of cucumber seedlings was carried out 30 days after planting the seedlings in greenhouse conditions. From the data given in Table 4, it follows that the height of the seedling grown from seeds treated with AKKU-36 at 0.001% was higher compared to the control on the 10^{th}, 20^{th}, and 30^{th} days, recording 11.5, 20, and 18.8 cm; while at 0.0001%, 15.4, 25.3 and 26.8 cm, respectively. Using standard leads to a slight increase in the height of cucumber seedlings. The number of leaves on one plant grown from seeds treated with AKKU-36 at 0.001% increased by 2 compared to the control on the 10^{th}, 20^{th}, and 30^{th} days (3.1 and 4.7 pcs.); while at 0.0001% by 2.5 (4 and 7.6 pieces), respectively. The number of leaves increased when seeds were treated at 0.002% compared to the control, with an increase of 1.1, 3.4, and 2.5 pcs. Thus, plants

grown from seeds treated with the drug (preparation) in optimal concentrations grew and developed much better, which, in turn, positively affected the growth of cucumbers (Table 4).

Table 4. The intensity of seedlings and development phases of cucumbers under the influence of treatment on crops with AKKU-36.

Types of Experiment	Seedlings					
	10 days		20 days		30 days	
	Plant height	Number of leaves	Plant height	Number of leaves	Plant height	Number of leaves
Control, without treatment	7.0	4.3	13.0	5.6	23.2	5.1
AKKU-36 0.01%	12.0	8.3	20.0	9.3	35.6	7.5
AKKU-36 0.001%	18.5	6.3	33.0	8.3	42.0	9.8
AKKU-36 0.0001%	22.4	7.8	38.3	9.6	50.0	12.7
Succinic acid solution (0.002%; standard)	10.0	5.2	15.0	8.3	38.0	7.6

Experiment 2.2. Study the effect of the drug (preparation) on the awakening of cucumber fruit tubers (greenhouse experiment)

The results of greenhouse studies showed that treatment of cucumber tubers with AKKU-36 at 0.001% increases the number of awakened tuber fruits by 20.0% compared to the control. Once pruning cucumber plants using treatment methods, all types of experiment were treated the same. Treatment of tubers with AKKU-36 at 0.0001% increased the number of awakened fruit tubers by 25.0% compared to the control (Table 5; Fig. 2).

An increase in the number of sprout tubers (Table 5) occurs by awakening parts of the tubers with a new substance, which in the control variant (as usual) did not awaken. When treating cucumber fruit tubers with succinic acid solution (0.002% standard), there was 9% more compared to the control option (Diagram 1).

Table 5. The effect of the new drug (preparation) AKKU-36 on the awakening of cucumber fruit tubers.

Types of Experiment	Cucumber	
	Number of fruit crops	Percentage compared to control
Control, without treatment	7	100
AKKU-36 0.01%	15	115
AKKU-36 0.001%	20	120
AKKU-36 0.0001%	25	125
Succinic acid solution (0.002%) (standard)	9	109

Consequently, treating cucumber seedlings after flowering with the drug (preparation) in optimal concentration increased the growth of cucumber plants in greenhouse conditions. Thus, the increases in the weight of cucumber fruits in the AKKU-36 variant at 0.001% on the days 30, 45 and 60 were 15.9, 23.2 and 35.2 g, while at 0.0001% were 18.5 , 22.4 and 32.4 g.

Table 6. dynamics of growth of cucumber fruit mass.

Types of Experiment	Weight of cucumber fruits. g.		
	30 days	45 days	60 days
Control, without treatment	8.0	15.3	27.5
AKKU-36 0.01%	12.0	18.3	28.3
AKKU-36 0.001%	15.9	23.2	35.2
AKKU-36 0.0001%	18.5	22.4	32.4
Succinic acid solution (0.002%) (standard)	11.7	17.5	23.5

Fig. 2. The flowering period of cucumbers and tomatoes in the greenhouse.

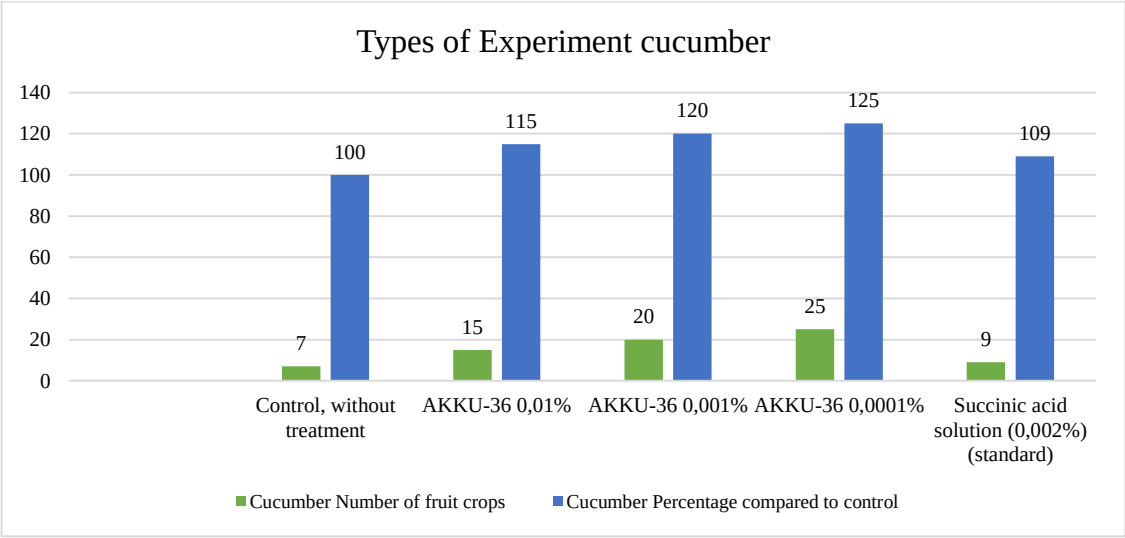

Diagram 1. Types of Experiment cucumber.

When using succinic acid solution (0.002%) standard, the weight gains were 11.7, 17.5, 23.5 g, while the control were 8.0, 15.3 and 27.5 g respectively (Table 6). Data on the yield of cucumber fruits, (Table 7), depict that pre-sowing treatment of cucumber seeds with AKKU-36 at 0.001% increases the yield by 3.6 ton ha^{-1} or 18.5% compared to the control and by 5.4 ton ha^{-1} or 21.8% at 0.0001%. Treatment with a 0.002% solution of succinic acid led to a rise in yield by 1.2 ton ha^{-1} or 6.5% compared to the control.

Experiment 3. The effect of AKKU-36 on the growth, development and productivity of tomatoes during pre-sowing seed treatment

Phenological observations of the growth and development of tomato plants showed that seeds treated with 0.001 and 0.0001% solutions grew three and five days earlier than observed. The phase of 2-4 and 6-8 leaves was also ahead of the control variant: in 0.001% three days, and in 0.0001% five days (Table 8).

Table 7. Effect of the drug (preparation) on the yield of cucumbers, variety "PHOENIX".

Types of Experiment	Cucumber yield (ton/ha)	Growing control	
		ton ha^{-1}	%
Control, without treatment	20.0	5.3	-
AKKU-36 0.01%	21.0	4.2	17.0
AKKU-36 0.001%	23.8	5.8	18.5
AKKU-36 0.0001%	25.4	6.5	21.8
Succinic acid solution (0.002%; standard)	21.2	3.2	6.5

Note: P (%): 4.5. HCP $_{0,05}$ (ton ha^{-1}): 0.8.

Table 8. Influence of the new drug (preparation) on the formation and development phase of tomatoes.

Types of Experiment	Seedlings		2-4 Leaf phase	6-7 Leaf phase
	Primary	Massive		
Control, without treatment	25.12	01.01	11.01	24.01
AKKU-36 0.01%				
AKKU-36 0.001%	22.12	30.12	08.01	20.01
AKKU-36 0.0001%	19.12	26.12	06.01	18.01
Succinic acid solution (0.002%; standard)	24.12	01.01	10.01	22.01

Experiment 3.1. Study the effect of the drug (preparation) on the growth rate of primary tomato seedlings (greenhouse experiment)

The positive effect of treating tomato seeds with solutions of the drug (preparation) persisted until the end of the growing season. Seedlings, groomed in the laboratory, were planted in the greenhouse on 01/25/23—the results of biometric measurements evidence this. Analyses of the data given in Table 9 shows that plants grown from seeds treated with AKKU-36 at 0.001 and 0.0001% were 5.3, 7.8, 6.5 cm and 7.2, 9.0, 8.1 cm above control plants (on reporting days); in standard by 3.0, 6.0 and 1.5 cm. On the 60th day after emergence, the number of leaves was 1.3-4.6 more for AKKU-36 (0.001 and 0.0001%); In the case of Standard solution, it was 2.7 pcs. (Table 9). On the 10th, 20th, and 30th days of recording, the weight of cucumber crops obtained from seeds treated with the new drug (preparation) AKKU-36 was more remarkable than in control (3.7, 4.8, 15.0 g for 0.001%, while 4. 0, 6.1, 17.3 g for 0.0001%, respectively). Pruning work for tomatoes grown in greenhouse conditions was carried out identically for all practices. The AKKU-36 preparation activated the growth and development of cucumber plants during seed treatment, which, in turn, increased tomato yield (Table 10). Thus, when treating tomato seeds with AKKU-36 at 0.0001%, the maximum increase in control was obtained and amounted to 6.3 ton ha^{-1} or 21.2% (Table 11). Plants grown from treated seeds grew and developed well, distinguished by the presence of 20-25, on average, 15-17 g of tomato crops in one cyst. This was followed by an elevation in the mass of the above-ground parts of the plants, the intensity of which was observed until the end of the growing season.

Table 9. Changes in the growth and development of tomato plants after seed treatment with a new drug (preparation).

Types of Experiment	Seedlings					
	10 days		20 days		30 days	
	Plant height	Number of leaves	Plant height	Number of leaves	Plant height	Number of leaves
Control, without treatment	9.0	6.2	10.0	8.3	17.0	8.3
AKKU-36 (0.01%)	12.5	7.2	15.0	9.2	21.0	10.0
AKKU-36 (0.001%)	14.3	9.1	17.8	13.5	23.5	14.0
AKKU-36 (0.0001%)	16.2	8.9	19.2	14.7	25.1	15.7
Succinic acid solution (0.002%) (Standard)	12.0	6.3	16.0	11.4	18.5	12.3

Table 10. Dynamics of weight growth of tomato crops (variety yellow cream) from seeds treated with the new drug (preparation) AKKU-36.

Types of Experiment	Weight of tomato crops, g.		
	30 days	45 days	60 days
Control, without treatment	13.2	24.2	35.0
AKKU-36 0.01%	14.5	25.0	44.3
AKKU-36 0.001%	16.9	29.0	50.0
AKKU-36 0.0001%	17.2	30.3	52.3
Succinic acid solution (0.002%; Standard)	12.2	27.1	40.0

Table 11. Effect of the new drug (preparation) on the yield of tomatoes of the "yellow cream" variety.

Types of Experiment	Tomato yield. (ton ha^{-1})	Growing control	
		t/ha	%
Control. without treatment	15.0	1.3	-
AKKU-36 0.01%	17.0	2.0	14.4
AKKU-36 0.001%	10.2	5.8	20.3
AKKU-36 0.0001%	22.1	6.3	21.2
Succinic acid solution (0.002%; Standard)	22.6	2.6	9.0

Note: P (%): 3.5. $HCP_{0,05}$ (ton ha^{-1}): 0.7.

CONCLUSIONS

Based on the project "IP202407: "Investigation of the direction of solving world problems by integrating SDGs into the educational process", the following conclusions were made in this study, and a utility model patent was awarded (Dzhienbaev *et al.* 2023):

1. The new compound AKKU-36 demonstrated clear plant growth-stimulating properties.
2. It was established that the optimal concentration of the drug (preparation) AKKU-36 is 0.0001%.
3. When the seeds of cucumber and tomato tubers were treated with the drug (preparation) indicated in optimal doses, plant shoots appeared 3-6 days earlier.
4. Treatment of tomato seeds with AKKU-36 at 0.001% showed that the intensities of plant growth were high: 5.3, 7.8, 6.5 cm, while at 0.0001% were 7.2, 9.0, 8.1 cm respectively.
5. The study drug (preparation) had a positive effect on cucumber tuberization. At the first stage of detection (the 45th day after germination) in the variant with the drug (preparation) AKKU-36 at 0.0001%, there were an average of 23 cucumbers on 1 branch, while in a similar concentration variant, 15 cucumbers.
6. Field tests have shown that plants grown in the tested greenhouse conditions grow and develop better from seeds and seeds treated with the synthetic drug (preparation) AKKU-36. On the 10th, 20th, and 30th days of recording, the weights of cucumbers obtained from seeds treated with the new drug (preparation) AKKU-36 were greater than the control (3.7, 4.8, 15.0 g, and 4.0, 6.1, 17.3 g for 0.001 and 0.0001%, respectively). When processing tomato crops, they were distinguished by the presence of 20-25 pieces in one cyst and an average of 15-17g of tomato crop mass.

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