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Influence of electrochemically activated water on the germination

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Abstract. The article is devoted to the study of the effect of electrochemically activated water (EAW) on the germination energy, germination, growth, and development of local varieties of crops, such as melon (Kichkintoi), watermelon (Kuziboi-30), and pumpkin (Ispanskaya-73), in the conditions of Uzbekistan. The studies included both laboratory and field experiments, which allowed us to obtain a comprehensive understanding of the effect of EAW on the sowing and agronomic qualities of these crops. In laboratory conditions, it was found that seed treatment with anolyte, catholyte, and their mixtures contributes to a significant increase in germination energy and germination. Anolyte (A1) showed the best results, providing maximum indicators for all crops, which indicates its high disinfectant and stimulating effect. Field experiments confirmed the laboratory results, demonstrating an improvement in plant growth indicators: an increase in the number of leaves, the formation of lateral shoots, and an increase in plant height. The results emphasize the importance of using EAW to increase yields, improve crop resistance to adverse factors, and environmental safety of agricultural production. These data can form the basis for the introduction of new technologies for pre-sowing seed treatment in Central Asia.

1 Introduction

Modern agriculture faces the challenges of increasing crop productivity and ensuring the environmental safety of production processes. In recent years, there has been growing interest in the use of innovative methods of seed treatment and plant protection that not only improve crop germination and growth but also reduce their susceptibility to pathogens without harming the environment [1-5]. One such method is the use of electrochemically activated water (EAW), an environmentally friendly product that has both stimulating and protective properties [7-9].

Watermelon (*Citrullus lanatus*), melon (*Cucumis melo*), and pumpkin (*Cucurbita pepo*) seeds occupy an important place in agricultural production in Uzbekistan, where these crops play a key role in food security and exports. However, their cultivation is associated with several problems. Firstly, there is a need to increase seed germination and ensure uniform

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growth of seedlings. Secondly, these crops are susceptible to phytopathogens and unfavorable climatic conditions, such as high temperatures and unstable humidity, which significantly affect their yield. Traditional seed treatment methods, such as chemicals or heat treatment, are often either ineffective or lead to negative consequences, including reduced germination energy, accumulation of toxic residues in the environment, and increased production costs [10-15].

The use of physicochemical methods of seed and plant activation, such as ultraviolet, ultrasound, electric fields, and magnetized water treatment, has proven its effectiveness in improving the growth and productivity of various crops [16-17]. For example, magnetized water increases the height of soybean plants by 40%, sunflowers by 21%, corn by 26%, and onion and carrot plant height increases by 22% with simultaneous thickening of stems [18-26]. These results emphasize the versatility of activation methods that stimulate physiological processes in seeds and improve growth parameters at the early stages of plant development.

Exposure to ultraviolet irradiation increases the germination of grain crop seeds by 2-10%, and wheat yield after treatment increases by 19-29% [18-26]. Ultrasonic treatment improves germination energy in radishes, lettuce, wheat, and flax, while exposure to an electric field accelerates the growth of cucumber seedlings and increases yield by 19% [25]. These methods show that physical and chemical stimuli are capable of regulating physiological processes through the activation of phytohormones such as auxins and gibberellins, improving plant adaptation to stress and increasing their productivity.

EAW is a promising method of seed treatment based on the electrochemical activation of water. The products formed during electrolysis, anolyte and catholyte, have unique physicochemical properties, including oxidation-reduction potential (ORP) and the ability to affect biological objects at the cellular level [1-5]. Anolytes exhibit pronounced antimicrobial properties, while catholyte stimulate growth processes by creating a favorable alkaline environment and activating enzymatic reactions. It is assumed that the combined use of these EAW fractions in seed treatment can significantly improve their germination, stimulate the initial growth of seedlings, and increase resistance to pathogens [1-5]. Previous studies demonstrate that EAW is effectively used to treat seeds of various crops, such as wheat, barley, sunflower, and corn. However, there is a limited amount of data on the effect of EAW on watermelon, melon, and pumpkin seeds, which have their unique morphophysiological features. In addition, many studies do not take into account such factors as electrolysis parameters, composition of the source water, and duration of treatment, which can significantly affect the results.

This study is especially relevant in the conditions of Uzbekistan, where climatic and soil characteristics require the adaptation of innovative technologies to specific regional conditions. The use of EAW as an environmentally friendly means for increasing seed germination and plant resistance opens up new prospects for sustainable agriculture in the region.

The purpose of this work is to study the effect of electrochemically activated water on the sowing qualities of watermelon, melon, and pumpkin seeds.

2 Materials and methods

2.1 Research objects

Fresh seeds of watermelon (*Citrullus lanatus*), melon (*Cucumis melo*), and pumpkin (*Cucurbita pepo*), represented by varieties typical for the conditions of Uzbekistan, were used for the experiment. These varieties are distinguished by their resistance to unfavorable environmental factors, high productivity, and good fruit characteristics, which makes them ideal for studying the effect of electrochemically activated water.

The Kichkintoi variety belongs to mid-season melons with a vegetation period of 75-80 days. The fruits are spherical, medium in size, and weigh from 0.8 to 1.2 kg. The peel is smooth, bright yellow, and covered with a fine mesh. The pulp of the fruit is light green, dense, tender, and has a pleasant aroma. The sugar content reaches 11.84%, which makes the variety attractive to consumers. The yield of the variety is 19-22 t / ha. In addition, the variety is resistant to common diseases such as powdery mildew.

The Kuziboi 30 variety is late-ripening, with a vegetation period of 120-130 days. The fruits are round, dark green, sometimes almost black, with thin, weakly expressed stripes. The average fruit weight is 5-6 kg, and the peel of the fruit is very hard, which allows the harvest to be well preserved in winter and transported over long distances. The pulp is light red, juicy, sweet, sometimes with a fibrous structure. The sugar content is 6.8%, and the yield of the variety reaches 35-40 t / ha. The variety is also distinguished by drought resistance and the ability to retain its qualities for a long time.

The "Ispanskaya-73" variety is a late-ripening variety with a vegetation period of 117-130 days. The fruits are flat-round, segmented, and gray-green. The length of the stalk is 6-7 cm, and it is significantly thickened, which ensures resistance to mechanical damage. The average weight of the fruit varies from 3.3 to 4.4 kg. The pulp is yellow, dense, and sweet, which is confirmed by a high tasting score of 5.0 points. The dry matter content is 14.7%, sugar - 12.0%, and carotene - 70 mg /%. The yield reaches 25-30 t / ha. The fruits of this variety are distinguished by excellent keeping quality, which makes them ideal for long-term storage in winter. These varieties were selected for the study because they demonstrate high adaptation to the conditions of Uzbekistan, including a hot climate and limited water resources. Studying the effect of electrochemically activated water on the seeds of these crops will help determine its effectiveness in increasing the germination and resistance of plants.

Fig. 1. Research objects.

For the study, seeds of uniform size and shape were selected manually and stored at 4°C until use. Before the experiment, the seeds were treated to remove external contaminants, after which the initial microbial contamination was determined to be within 6 log CFU/g.

2.2 Preparation of solutions

Electrochemically activated water (EAW) was obtained by dissolving 10 g KCl in 10 l distilled water with subsequent electrochemical treatment in a diaphragm electrolyzer. Electrolysis conditions: voltage 8 V, current 0.7 A, flow rate through the anode chamber - 4 l/h, through the cathode - 1 l/h. The resulting anolyte and catholyte were mixed in a ratio of 16:1. The mixture was then diluted with distilled water to various concentrations, or solutions were prepared by mixing catholyte and anolyte in various ratios.

2.3 Seed treatment

Each seed sample (25 g) was placed in a 250 ml beaker and soaked in the treated EAW solution (of different concentrations) for 5 minutes. After soaking, the seeds were washed with 250 ml of distilled water to remove the remaining solution. Seeds treated only with distilled water were used as a control.

2.4 Microbial load assessment

The total number of bacteria on the seeds was assessed before and after treatment with EAW. The microorganism count was performed according to ISO 9308-1:2000. For this purpose, the seeds were incubated at 37 °C for 24 hours. After incubation, the number of bacteria was determined in logarithmic units (log CFU/g).

2.5 Evaluation of germination and initial growth

After treatment, the seeds were placed in Petri dishes on filter paper moistened with distilled water. Germination was observed for 7 days at 25 °C. The following parameters were used for evaluation: germination percentage (%); germination energy (%); length of roots and sprouts (mm).

2.6 Physicochemical properties of solutions

The pH and oxidation-reduction potential (ORP) of the EAW were measured using a SevenDirect SD50 pH/Ion meter (Mettler Toledo). The concentration of active chlorine was determined by the iodometric method [26] and photometric analysis using the N, N-diethyl-p-phenylenediamine reagent on a UV-5100 spectrophotometer.

2.7 Determining the percentage of germination

The germination percentage of watermelon, melon, and pumpkin seeds was determined using a modified method. Samples of 5 g of seeds treated with different solutions of electrochemically activated water (EAW) and controls were placed on sterile moistened cotton pads in plastic containers. Incubation was carried out at 25 °C (±2 °C) for 3 days, with regular addition of distilled water to maintain the required humidity level. After incubation, the total number of seeds and germinated seeds in each container were counted, and the germination percentage was determined as the ratio of the number of germinated seeds to the total number of seeds, multiplied by 100%.

2.8 Determination of seedling growth

To assess the growth of watermelon, melon, and pumpkin sprouts, 100 sprouts from the germinated seeds of each experimental variant (EAW-treated and control) were left for further growth on moistened filter paper in the same containers. Incubation lasted 4 days under the same conditions (25 °C, high humidity). After that, the length of the roots and stems of the sprouts was measured with a ruler with an accuracy of 1 mm. The average values of the sprout length were calculated for each group.

3 Results and discussion

Tap water taken from the municipal water supply system of Namangan was used for the experiment. The water is characterized by a neutral reaction to the environment, its pH is 7.1. The concentration of active chlorine (ACC) in tap water was below 0.3 ppm, which indicates a minimal content of chlorine-containing compounds. The oxidation-reduction potential (ORP) of tap water was -228 mV. This value indicates its weak oxidizing ability. Such characteristics make tap water a basic control solution, which allows comparing its properties with solutions treated by the electrochemical activation method. Using water with known and stable characteristics as a control ensures the accuracy and reliability of the experimental results. Electrochemically activated water (EAW) used in the study has unique physicochemical characteristics that ensure its effectiveness for seed treatment. The pH value of EAW was 6.6, which indicates its slightly acidic nature, close to neutral. This makes the solution safe for seeds, eliminating the possibility of damaging their shells during processing, and at the same time promoting the activation of physiological processes.

The concentration of active chlorine (ACC) in the solution reached 28.6 ppm, which indicates a high oxidizing capacity of water. The presence of active chlorine provides antimicrobial properties of the solution, destroying pathogenic microorganisms on the surface of seeds and creating sterile conditions for their germination. This property is especially important for preventing diseases in the early stages of plant growth.

The oxidation-reduction potential (ORP) of the solution was 850 mV, which indicates its strong oxidizing properties. High ORP activates metabolic processes in seed cells, promotes acceleration of metabolism, and stimulates the initial phases of germination.

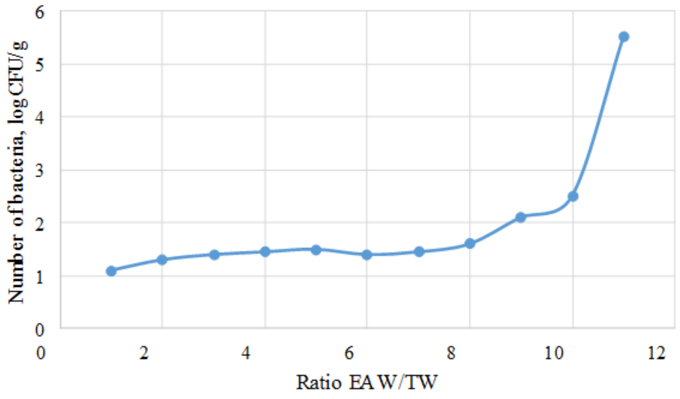
Based on this water, various solutions were prepared by mixing with tap water in various proportions, the results of which are given in Table 1.

Table 1. Changes in the main water parameters, at different ratios TW/EAW.

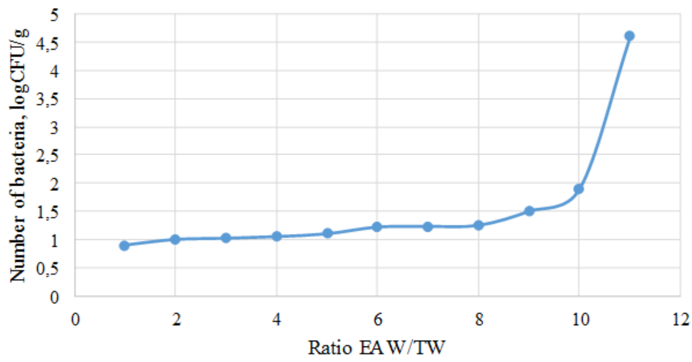
TW/EAW ratio	pH	ACC, (ppm)	ORP (mV)
1/9	6,6	24,5	793
2/8	6,6	22,1	736
7/3	6,6	17,4	679
6/4	6,7	16,7	622
5/5	6,7	13,9	565
4/6	6,8	11,1	508
3/7	6,9	8,4	451
2/8	7,0	5,1	394
1/9	7,1	2,3	337

The analysis of the data presented in Table 1 shows changes in the main water parameters with varying ratios of tap water (TW) and electrochemically activated water (EAW). As the proportion of tap water in the mixture increases, there is a tendency for pH to increase from 6.6 to 7.1, which reflects a gradual decrease in the acidity of the solution. At the same time, there is a significant decrease in the concentration of active chlorine (ACC) - from 24.5 ppm at a minimum proportion of TW (1/9) to 2.3 ppm at a maximum proportion of TW (9/1). The oxidation-reduction potential (ORP) also decreases - from 793 mV to 337 mV, indicating a loss of the oxidizing properties of the solution. These changes show that diluting EAW with tap water reduces its antimicrobial and activating properties, which is important to consider when choosing ratios for seed treatment.

Seed germination is a key indicator of their sowing qualities. As part of laboratory research, a series of experiments were conducted using activated tap water of appropriate quality to assess the germination energy and viability of grain and legume seeds.



a)



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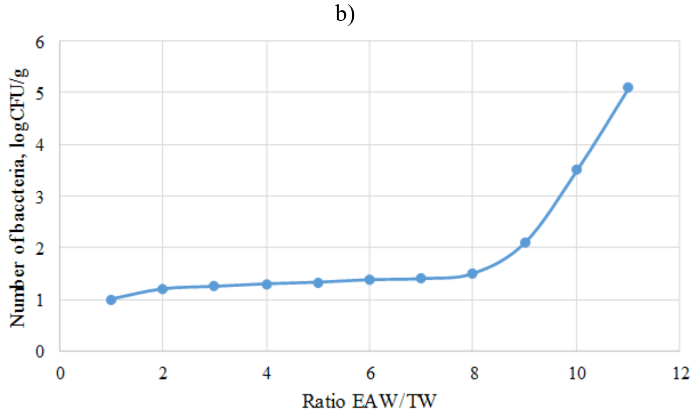

c)

Fig. 2. Change in the number of bacteria (logCFU/g) from the ratio of EAW/TW during treatment: a) melon; b) watermelon; c) pumpkin.

The graphs show changes in the bacterial count (logCFU/g) on the surface of melon, watermelon, and pumpkin seeds depending on the ratio of electrochemically activated water

(EAW) to tap water (TW). The data show that the concentration of EAW has a significant effect on reducing the bacterial load on the seed surface.

Melon seeds show the most pronounced reduction in the bacterial count at a high EAW concentration. At a ratio of 1:0 (the maximum proportion of EAW), the bacterial level is 1.1 logCFU/g, but as the proportion of EAW in the solution decreases, the bacterial count increases significantly, reaching 5.5 logCFU/g in the complete absence of EAW (0:1). This indicates a strong dependence of the antimicrobial effect on the concentration of the activated solution.

Watermelon seeds generally show a lower bacterial load compared to melon and pumpkin. At a ratio of 1:0, the bacterial level is minimal - 0.9 logCFU/g, and in the complete absence of EAS, it increases to 4.6 logCFU/g. Watermelon shows a more gradual increase in bacterial load with a dilution of EAW, which indicates its relative resistance to microbial contamination.

Pumpkin seeds show the sharpest increase in bacterial load with a decrease in the proportion of EAW. At a ratio of 1:0, the bacterial level is 1 logCFU/g, but at a ratio of 0:1 (tap water only), the number of bacteria increases sharply to 5.1 logCFU/g. This indicates the need to use high concentrations of EAW for the effective treatment of pumpkin seeds.

In general, electrochemically activated water is most effective in reducing the bacterial load on watermelon seeds, even when diluted. For melon and pumpkin seeds, the treatment efficiency is more sensitive to changes in the concentration of EAW. The maximum bacterial load in the absence of EAW is observed in melon (5.5 logCFU/g), then in pumpkin (5.1 logCFU/g), and the minimum in watermelon (4.6 logCFU/g). These differences indicate the need for individual selection of processing parameters for each type of seed.

To assess the effect of electrochemically activated (ECA) water on the germination energy of melon seeds, studies were conducted using different types of water with different physicochemical characteristics. The experiment included an analysis of the effectiveness of the following solutions:

1. Original tap water with neutral pH 7.1 and ORP +289 mV, which served as a control sample;
2. Catholyte (C1) with pH 11.3 and negative ORP -686 mV, possessing alkaline reaction and reducing properties;
3. Acidic anolyte (A1) with pH 3.4 and high positive ORP +931 mV, characterized by pronounced oxidizing and antimicrobial properties;
4. Neutral anolyte (A2) with pH 6.2 and ORP +691 mV, possessing a balanced combination of oxidizing properties;
5. The mixture of anolyte and catholyte in a ratio of 1:1 (AC1/1), with pH 6.9 and ORP +212 mV, representing a softer neutral solution;
6. A mixture of anolyte and catholyte in a ratio of 1:4 (AC1/4), with a pH of 6.9 and an ORP of +556 mV, demonstrating moderate oxidation-reduction properties.

The data on the effect of ECA water on the germination energy and germination of melon seeds are presented in Table 2. The analysis made it possible to identify which of the studied solutions most effectively stimulates the initial stages of germination, and also helps to determine the optimal conditions for pre-sowing seed treatment.

Table 2. Effect of different types of water on germination energy, viability, and proportion of non-germinating seeds.

Water type	Germination energy, %			Germination, %			Unsprouted seeds, %		
	Melon	Watermelon	Pumpkin	Melon	Watermelon	Pumpkin	Melon	Watermelon	Pumpkin
TW	23,1	27,2	31,2	24,7	26,2	30,5	75,3	73,8	69,5
C1	42,6	39,5	70,5	76,5	81,2	83,2	23,5	18,8	16,8
A1	59,8	67,6	78,5	94,1	88,5	91,8	5,9	11,5	8,2
A2	51,3	49,6	52,5	58,5	33,5	53,5	41,5	66,5	46,5
AC1/1	41,3	44,5	68,8	71,2	69,8	75,4	28,8	30,2	24,6
AC1/4	48,9	56,5	73,5	75,3	74,2	82,2	24,7	25,8	17,8

The results of the study (Table 2) demonstrate the influence of different types of water on the germination energy, germination capacity, and the proportion of ungerminated seeds of melon, watermelon, and pumpkin. These indicators vary significantly depending on the physicochemical properties of the water used.

The use of tap water (TW) is characterized by minimal efficiency for all the parameters studied. The germination energy when using TW for melon, watermelon, and pumpkin seeds is 23.1%, 27.2%, and 31.2%, respectively. Germination for the same crops reaches only 24.7%, 26.2%, and 30.5%, which is accompanied by the largest number of ungerminated seeds: 75.3% for melon, 73.8% for watermelon, and 69.5% for pumpkin. These data confirm the low efficiency of tap water as a treatment solution for seeds. Catholyte (C1), which has an alkaline reaction and reducing properties, significantly improves sowing indicators. The germination energy of melon, watermelon, and pumpkin seeds increases to 42.6%, 39.5%, and 70.5%, and the germination rate reaches 76.5%, 81.2%, and 83.2%, respectively. The number of ungerminated seeds when using C1 decreases to 23.5% for melon, 18.8% for watermelon, and 16.8% for pumpkin. These results confirm the stimulating effect of catholyte on the initial stages of seed germination. Acidic anolyte (A1) shows the best results among all types of water. The germination energy for melon, watermelon, and pumpkin seeds is 59.8%, 67.6%, and 78.5%, respectively, and the germination rate reaches 94.1%, 88.5%, and 91.8%. The share of non-germinated seeds is minimal: 5.9% for melon, 11.5% for watermelon, and 8.2% for pumpkin. The high efficiency of A1 is explained by its pronounced oxidative and antimicrobial properties, which help eliminate pathogens and stimulate metabolic processes in seeds. Neutral anolyte (A2) demonstrates less pronounced results compared to A1. The germination energy is 51.3%, 49.6%, and 52.5% for melon, watermelon, and pumpkin seeds, respectively, and the germination rate reaches 58.5%, 33.5% and 53.5%. The number of ungerminated seeds remains relatively high: 41.5% for melon, 66.5% for watermelon, and 46.5% for pumpkin. These data indicate that neutral anolyte is inferior to acid anolyte in efficiency.

Mixtures of anolyte and catholyte (AC1/1 and AC1/4) show intermediate results. For the mixture AK1/4, higher germination energy (48.9% for melon, 56.5% for watermelon, and 73.5% for pumpkin) and germination (75.3%, 74.2% and 82.2%, respectively) are observed compared to AC1/1. The number of ungerminated seeds when using AC1/4 is lower: 24.7% for melon, 25.8% for watermelon, and 17.8% for pumpkin. This indicates that the ratio of components in the mixture affects the efficiency of treatment. Thus, acidic anolyte (A1) and catholyte (C1) are the most effective solutions for seed treatment, providing high rates of germination energy and germination. Neutral anolyte and anolyte-catholyte mixtures show moderate results, while tap water is the least effective in stimulating seed germination. The effect of ECA on the growth of melon and watermelon seedlings and roots (results of a laboratory experiment, 2021-2024) over 7 days is given in Table 3.

Table 3. Effect of ECA on the growth of seedlings and roots (after 7 days).

Water type	melon		watermelon	
	root length, mm	sprout length, mm	root length, mm	sprout length, mm
A1	61	78,9	73,3	101,3
A2	53	68,8	68,5	81,5
C1	54	73,3	61,3	88,6
TW	47	61,2	56,2	72,5

The results of the experiment presented in the table demonstrate the effect of different types of water on the growth of roots and sprouts of melon and watermelon 7 days after treatment. The analysis of the data reveals both similarities and differences in the reaction of the seeds of both plants to different types of water.

In all the studied types of water, a pattern is observed: the length of the sprout exceeds the length of the root in both melon and watermelon. This is expected since the growth of sprouts often exceeds the growth of roots in the initial stages of germination. In addition, acid anolyte (A1) provides the greatest length of roots and sprouts in both plants, which indicates its high efficiency in stimulating growth. For example, for melon, the length of the root and sprout is 61 mm and 78.9 mm, and for watermelon - 73.3 mm and 101.3 mm, respectively, which are the maximum values among all types of water.

Also, the general trend for both plants shows that tap water (TW) has the least efficiency. The length of roots and sprouts when using BB is significantly lower compared to the treatment with ECA water. For melon, the root length is 47 mm, and the sprout length is 61.2 mm, while for watermelon these figures are 56.2 mm and 72.5 mm.

The differences between melon and watermelon are manifested in the degree of reaction to different types of water. Watermelon shows higher growth rates of roots and sprouts compared to melons with almost all types of water. For example, when treated with acidic anolyte (A1), the length of the watermelon root is 73.3 mm, which is 12.3 mm longer than that of melon. Similarly, the length of the watermelon sprout (101.3 mm) significantly exceeds this figure for melon (78.9 mm).

In addition, neutral anolyte (A2) and catholyte (C1) demonstrate different efficiency for plants. In melon, catholyte (C1) ensures a greater sprout length (73.3 mm) compared to neutral anolyte (68.8 mm), whereas in watermelon, neutral anolyte stimulates greater sprout growth (81.5 mm) compared to catholyte (88.6 mm). This difference may be due to the different physiological characteristics of the seeds and their response to the properties of the solutions.

The analysis shows that acid anolyte (A1) is the most effective in stimulating the growth of both roots and sprouts in both crops, while tap water (TW) shows minimal results. Watermelon responds more actively to the treatment, showing a greater increase in the length of roots and sprouts compared to melon. Differences in the effectiveness of neutral anolyte and catholyte emphasize the importance of choosing the type of water depending on the physiological characteristics of the seeds being treated. These data confirm that ECA water can significantly improve the initial stages of plant growth, which is of great importance for increasing crop yields and sustainability. Similar studies were conducted on pumpkin seeds not only in the laboratory but also in the field, which allowed us to get a more complete picture of the effect of ECA water. The experiments were conducted in triplicate. For each treatment option, 20 high-quality and hand-selected pumpkin seeds were selected. All seeds in different treatment options were moistened with the appropriate water solutions and wrapped in gauze, then left at a temperature of 24-25 ° C for 24 hours for preliminary swelling.

In the first treatment option, pumpkin seeds were treated with ordinary tap water (pH = 7.1), which was used as a control sample.

The sowing of swollen seeds was carried out on February 26, 2024. For this, the seeds were placed in polymer containers, taking into account all agrotechnical requirements. Each crop was sown in separate cells with an indication of the treatment option indicated on the labels. To ensure the reliability of the results, sowing was carried out with three replicates. The obtained data will allow us to evaluate how various water compositions, including ECA water, affect the key parameters of pumpkin growth and development in real conditions (Fig. 3).

The presented figures (Fig. 3) show the stages of experiments to study the effect of various types of water on the germination and development of pumpkin seeds in laboratory and field conditions. The first figure shows the initial stage of the experiment, where pumpkin seeds are sown in individual containers with moistened soil. The second figure shows the experimental setup in the field, where seedling cells are organized by treatment options. Each group of seeds is placed separately to analyze the effect of different types of water, such as anolyte, catholyte, and their mixtures, and a control group with tap water.

Fig. 3. Stages of field research on the effect of ECA water on the growth and development of pumpkin seeds.

The third figure shows the structure of the experiment with replication, where three repetitions of the experiment allow to minimize the influence of random factors and increase the accuracy of the results.

The analysis of the dynamics of pumpkin seed germination (Table 4), presented in the table, reflects the differences in the effectiveness of different types of water at three control stages of observation: April 2, April 9, and April 13, 2024. The experiments used 60 seeds for each treatment option, and the results demonstrated significant differences between the use of different waters.

Table 4. Dynamics of pumpkin seed germination depending on the type of water (total number of sown seeds - 60).

Water type	The number of germinated seeds, pcs		
	1-control check 02.04.2024	2-control check 9.04.2024	3- control check 13.04.2024
TW	0	28	48
C1	0	37	55
A1	1	38	57
AC1/1	0	39	58
AC1/4	1	38	58

During the first control check (04/02/2024), seed germination was observed only in two variants: acid anolyte (A1) and a mixture of anolyte and catholyte in a ratio of 1:4 (AC1/4), where a single seed germination was recorded (1 seed). For the remaining treatment variants, including the control group with tap water (TW), germination was absent at this stage. This indicates that the initial activation of germination processes is more pronounced when using an anolyte or its combinations with a catholyte. The second control check (04/09/2024) demonstrated a sharp increase in the number of germinated seeds. The largest number of germinated seeds was recorded in the AC1/1 (39 seeds) and C1 (37 seeds) variants. These data confirm that catholyte and mixtures of ECA water are highly effective in stimulating seed germination at the middle stages of development. Anolyte (A1) and the AK1/4 mixture showed the same result — 38 sprouted seeds, which also indicates the high efficiency of these solutions. At the same time, tap water (TW) showed the lowest result — only 28 sprouted seeds, which emphasizes its low activity in stimulating the initial stages of growth.

During the third control check (13.04.2024), the maximum number of sprouted seeds was recorded. The best results were observed in the AK1/1 and AK1/4 variants, where the number of sprouted seeds reached 58 pieces. Anolyte (A1) showed similar results — 57 sprouted seeds. Catholyte (C1) demonstrated slightly lower efficiency, reaching 55 sprouted seeds. The control group with tap water (TW) again showed minimal results — only 48 sprouted seeds. The obtained data show that the use of electrochemically activated water, especially in the form of anolyte and catholyte mixtures (AC1/1 and AC1/4), provides the greatest efficiency in accelerating and increasing the number of germinated pumpkin seeds. Anolyte (A1) and catholyte (C1) also demonstrate high activity, but their efficiency is inferior to mixtures. The control variant with tap water (TW) showed the lowest results, which confirms the need to use ECA water to increase seed germination. These results emphasize the importance of selecting the optimal type of water for pre-sowing seed treatment, which is especially important for improving agrotechnical indicators.

Table 5. Growth and development of pumpkin seedlings in an open area (total number of sown seeds-15).

Water type	Number of sheets			Number of lateral shoots			Plant height, cm		
	19.04	26.04	3.05	19.04	26.04	3.05	19.04	26.04	3.05
TW	1	2,2	4,8	-	-	5	5.2	6.3	8,2
C1	1	2,6	5,6	-	-	3	5.8	8.4	10,8
A1	1	2,2	5	-	-	7	6.1	9.6	13,8
AC1/1	1	2	5	-	-	7	5.6	8.1	11,2
AC1/4	1	2	5	-	-	6	5.4	7.8	10,6

The results of the experiment (Table 5) show the effect of different types of water on the growth and development of pumpkin seedlings during three observation periods: April 19 and 26, and May 3. Three parameters were used for the assessment: the number of leaves, the number of lateral shoots, and plant height.

At the initial stage (April 19), the same number of leaves was recorded in all variants - 1 leaf. By April 26, the greatest increase in the number of leaves was observed in the variants with catholyte treatment (C1) - up to 2.6. By May 3, the maximum number of leaves was noted in the variant with catholyte treatment (C1) - 5.6, which slightly exceeds the indicators of other variants (4.8-5.0).

Lateral shoots began to form only by May 3. The largest number of lateral shoots (7) was recorded in the variants with anolyte (A1) and the AC1/1 mixture, which indicates a stimulating effect of these types of water on the lateral development of plants. The variant with catholyte (C1) produced the smallest number of shoots (3).

At the early stage of the experiment (April 19), the plant height was similar in all variants (5.2–5.8 cm). By April 26, the seedlings treated with anolyte (A1) showed a maximum height of 9.6 cm. By May 3, this variant also demonstrated the greatest plant height of 13.8 cm, which is significantly higher than in the control group (8.2 cm). The variant with catholyte (C1) also showed good results, reaching 10.8 cm by May 3.

Treatment with different types of water had a noticeable effect on the growth and development of pumpkin seedlings. Anolyte (A1) proved to be the most effective, providing the maximum plant height and the largest number of lateral shoots. Catholyte (C1) showed the best results in the number of leaves, but was inferior to anolyte in lateral branching and the total height of the plants. Mixtures of anolyte and catholyte (AC1/1 and AC1/4) gave average results, surpassing the control variant, but inferior to individual anolyte and catholyte.

4 Conclusion

The conducted studies in Uzbekistan have shown a significant effect of electrochemically activated water (EAW) on the growth, development, and germination of seeds of local varieties of melons, watermelons, and pumpkins, such as the melon variety "Kichkintoi", watermelon "Kuziboi-30" and pumpkin "Ispanskaya-73". These studies are the first where these crops were studied in the context of using EAW, which makes the results unique and relevant for the conditions of the Uzbek agroclimatic zone. Laboratory experiments have demonstrated that seed treatment with anolyte, catholyte, and their mixtures significantly increased germination energy and germination. The most effective were acidic anolyte (A1) and its mixtures with catholyte (AC1/4), which showed a balance between antimicrobial activity and stimulation of metabolic processes in seeds. Such results are of particular value for local farmers who are faced with the need to increase crop yields in arid climates and unstable water supply. In field studies conducted for the first time for pumpkin varieties in Uzbekistan, it was found that the use of EAW has a positive effect on the number of leaves, plant height, and the formation of lateral shoots. These parameters significantly exceeded the indicators of the control groups, where only tap water was used. Anolyte, especially acidic, and its mixtures with catholyte have proven their effectiveness in improving vegetative growth and strengthening plant resistance to external factors. The study data confirm that pre-sowing treatment of local crop varieties with electrochemically activated water opens up prospects for increasing yields, improving sowing qualities, and reducing the costs of traditional chemicals. Considering that similar studies have not been previously conducted in Uzbek territories, the obtained results lay the scientific basis for further introduction of EAW into agricultural practice in the region. These data can form the basis for developing local recommendations for the use of EAW aimed at sustainable agriculture adapted to the climatic features of Uzbekistan.

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