Aerosol Management of Nutrients in Aeroponic Potato Mini-Tubers Cultivation Technology

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Abstract. The purpose of the article presented by the authors is to substantiate developments on improving the automated aeroponic technology for growing healthy seed potato mini-tubers, disclosing an improved technology for supplying charged aerosol droplets of nutrients. The article presents the results of testing the nutrient management system. The prospect is to realize the possibility of stimulating the root system by electrophysical factors that increase the efficiency of plant nutrition. The supply of nutrient aerosol to the roots of the plant is accompanied by the injection of a charged stream of oxygen into the chamber. This mixture is ejected from the improved nozzle under some pressure. Falling on the fibers of the root, the drops remain on the surface and do not roll down. There are also drawings showing the constructive novelty of aeroponic technology. It is recommended to use the electrostatic drip charging method. This method allows you to get a high dosage accuracy of plant root coverage. The prospect of such a modification is manifested not only in energy saving, but also in new possibilities for managing the growth of the root system.

1. Introduction

Liquid atomization is an important process used in aeroponic plant nutrition systems in advanced crop production systems. Basically, this technology is used to carry out root fertilization of agricultural crops with aerosols of nutrients in the air environment of an aeroponic box. For the production of aerosols, nozzles with high pressure pumps are used. Important characteristics of the spraying process are the size of the formed droplets, their concentration and spatial distribution. This affects the plant's ability to receive more nutrients and oxygen during the spraying period. The smaller the aerosol drop, the easier it becomes to deliver the solution. However, the distribution of a finely dispersed solution from the nozzle is ineffective to the roots due to the characteristics of the torch jet [1, 2, 3, 4].

One of the most promising ways to increase the efficiency of the process of spraying a nutrient solution in aeroponic technology is its preliminary saturation with a charged gas [5, 6]. The use of an electrostatic charge of sprayed liquid droplets increases productivity, improves the quality of plant coverage and improves plant nutrition [7].

The main principle of the method of electrostatic charge of droplets is spraying liquid through special nozzles with the simultaneous transfer of electric charge to small drops of nutrient solution flying out of the nozzle. The electrically charged fog, together with oxygen, evenly rushes to the roots and settles...
over the entire area of hairs with an opposite charge. There are several ways to charge drops, but in practice, two of them are most often used: ionic and contact.

Ionic charging is used in electronic ion technology devices due to its high efficiency and simplicity of the process. The source of ions is the corona discharge field arising in the space between the two electrodes, shown in figure 1, a. The charge arises as a result of the adsorption of ions by liquid droplets arising from the ionization of air. Having received a charge, the drops begin to move along the lines of the electric field in the direction of the object being processed.

Contact charging occurs as a result of contact of the working liquid solution with the sharp edge of the atomizer, which acts as a discharge electrode. A corona discharge occurs at the tip of the electrode edge, and electric charges flow into the air, as shown in figure 1, b. If you put and apply a thin layer of liquid on this edge of the nozzle, it will be charged. Then, under the action of the forces of the electric field, it stretches and flows from the surface in the direction of the object having the opposite charge. In this case, the charge level is 10–30 times higher than in the case of the ionic one. Thus, charging an aerosol of a nutrient can contribute not only to crushing the liquid, but also to the directed movement of small droplets to the roots of plants.

![Figure 1](image.png)

**Figure 1.** The charging circuit of the drops: a – ion; b-contact.

Research on the process of electrostatic spraying, both in Russia and abroad, is carried out on the basis of universities with funding from large firms. In the UK, the APE-80 sprayer is designed. The company Marwald of Florida (USA) has developed the KWH “Kinkelder” device. Farm Machinery Corp. (USA) has created a rod sprayer for field crops. The company SES (UK) has created a prefix to the hydraulic sprayer. The company SADKO (Ukraine) has developed a manual sprayer GMD-6014. However, the presented solutions are used in the field of plant protection and are used when applying drops to the tops of plants grown in the field.

A review of technical means for charging droplets of nutrient liquid showed that existing devices do not allow charging large volumes of sprayed liquid and are not used in aeroponic technology. This is due to the problems of electrical safety, as well as the lack of development of constructive electrophysical solutions for dosing and mixing based on biotechnological recommendations.

The closest research on the technical nature are works in literature sources [8, 9, 10]. The article [8] discusses innovative technologies for growing potato mini-tubers on aerohydroponic devices. The following works [9, 10] are devoted to both the influence of the concentration of dissolved oxygen in aerohydroponics on the formation and growth of adventitious roots, and the properties of a liquid polarized by electrostatic charges. The use of these factors in combination with the proposed technology allows the development of new methods of growing potato root crops and mini-tubers, taking into account the management of aerosols of nutrients.
2. Materials and methods
When spraying plants using standard methods, there are a number of disadvantages that affect the effectiveness of the use of aerosols of nutrients. The main disadvantages of the existing methods are: the polydispersity of sprayed drops, drift of drops to the electrified surfaces of the aeroponic body, low coverage density of the plant root system, adhesion of solution drops, resulting in a drain from the roots back to the solution node. This increases the operating time and frequency of pump activation, which wears out structural parts and clogs the injectors faster. All these disadvantages contribute to a decrease in the efficiency of the spraying system and root fertilization of plants. The proposed method of spraying agricultural crops eliminates these disadvantages.

The ion atomization technology (figure 2) consists of an air compressor 1, an ionizer 2, a mixer for injection solutions 3, an adjustable voltage source 4, a valve distributor 5, a membrane pump for supplying an ionized mixture 6, and a liquid source. Pump 7, reservoir for mineral solution 8, sprayers (nozzles) 9, treated potato plants 10 and controlled electrode for reverse osmosis 11.

![Figure 2](image)

Figure 2. Method of aeroponic feeding of agricultural crops with the supply of ionized nutrient aerosol:
1 – air compressor; 2 – ionizer; 3 – injection mortar mixer; 4 – controlled voltage source; 5 – valve distributor; 6 – membrane pump for the supply of ionized mixture; 7 – liquid supply pump; 8 – container for mineral solution; 9 – nozzles; 10 – treated plants; 11 – controlled electrode for reverse osmosis.

The method of spraying the root system functions as follows. The mineral solution for the plant (upper right) from the container 8 is supplied by the pump 7 under pressure to the injection mixer 3 along the sprayer line. Compressor 1 supplies air (upper left) to the ionizer 2. High voltage source 4 (at least 14 kV), connected to the ionizer electrodes. Under the action of a high voltage between the electrodes, the passing air is ionized (upper right) mainly by a negative charge. Next, the ionized air (upper right) from the ionizer is sent to the injection mortar mixer 3. On the other hand, the liquid (upper left) is fed from the container with the mineral solution 8, through the pump 7, to the injection mortar mixer 3. Now the ionized air (upper right) and the nutrient liquid (upper left) for the potato roots are mixed in the mortar mixer. At this point, the ion concentration should be observed in the range from 500 × 10³ cm⁻³ to 5000×10³ cm⁻³. At the outlet of the injection mortar mixer 3, an ionized liquid-air flow (upper right) is obtained, which enters the valve distributor 5. After distribution, the ionized liquid-air flow (upper right) is sent along the sprayer lines to the injectors 9. When leaving the nozzles of the injectors 9, the ionized liquid-air flow (upper right) is sprayed as an aerosol on the plant roots [5, 6]. At the same time, the ionized liquid with bubbles, flying out of the nozzles, regulates the
direction of its flight to the roots of plants. The direction of movement of fine droplets is determined by the action of the opposite charge on the root system of plants.

On the one hand, charged drops of the nutrient solution (–) fly out of the nozzles 9 onto the roots of the treated plant 10, and on the other hand, the water dispersion is attracted to the positively charged root hairs. This is due to the fact that the stems of potato plants are connected to the positive electrode 11 of the high voltage source 4. After that, the charged negative drops of mineral solution are evenly distributed on the hairs of the root system of the plants for feeding. This method of plant nutrition increases the surface area of the application of nutrients to the potato roots appendages. In particular, the uniformity of the distribution of fine droplets is improved, along with the effective dosing of oxygen to the roots. This principle is shown in figure 3.

**Figure 3.** Technology for obtaining nutritious ionized aerosol for plant feeding.

**3. Results**

The aim of the study is to determine the quality indicators of the application and distribution of charged fine liquid droplets on a surface with an opposite electric equipotential charge. Determination of quantitative and qualitative indicators of droplet spraying is carried out according to the method of testing sprayers with the use of accounting cards [11, 12]. The result of the application and distribution of liquid drops on the registration cards is recorded by macro photography (figure 4).
**Figure 4.** The result of applying drops to the registration cards: a – charged; b-uncharged.

To determine the efficiency of applying a liquid with a charge of fine droplets, a voltage was applied to the ionizer electrodes of 14 kV, 17 kV, and 20 kV. In the compared version, the control spraying was carried out without charging the drops. The results of the studies are presented in tables 1, 2.

**Table 1.** Distribution of droplets by size groups for the front side of the surface.

| Voltage, kV | Sizegroup, microns | Total, pcs |
|------------|--------------------|------------|
|            | 20-50 | 50-80 | 80-100 | 100-150 | 150-200 | >200 |  |
| 0          | 7     | 10    | 14     | 39     | 29      | 31   | 130 |
| 14         | 8     | 14    | 23     | 42     | 32      | 27   | 146 |
| 17         | 21    | 37    | 58     | 64     | 33      | 45   | 258 |
| 20         | 12    | 23    | 39     | 53     | 50      | 43   | 220 |

**Table 2.** Distribution of droplets by size groups for the back side of the surface.

| Voltage, kV | Sizegroup, microns | Total, pcs |
|------------|--------------------|------------|
|            | 20-50 | 50-80 | 80-100 | 100-150 | 150-200 | >200 |  |
| 0          | 0     | 8     | 18     | 23     | 16      | 10   | 75  |
| 14         | 9     | 14    | 22     | 17     | 23      | 17   | 102 |
| 17         | 20    | 42    | 40     | 34     | 20      | 12   | 168 |
| 20         | 23    | 44    | 50     | 35     | 25      | 16   | 193 |

Based on the study of the presented values, the results are obtained. It should be noted that due to an increase in the voltage at the ionizer electrodes, the density of application of registration cards by drops increases. There is an improvement in the efficiency of droplets hitting the surface of the card. Based on the data sample, an increase in the number of drops on the surface under study was found. The greatest increase in the coating density of the card is noticeable at voltages of 17, 20 kV and ranges from 57 to 150 %. The experiment also shows the attraction of negatively charged solution droplets to the surface of the card with the opposite charge. When the voltage applied to the ionizer increases, a strong ionization of the liquid occurs. Acquiring an electric charge of the same sign, the liquid jet splits into droplets that repel each other. As a result, there is an increase in the number of drops less than 100 microns. By acquiring a fine structure, the droplets are ionized faster. In this state, they are more susceptible to the Coulomb forces of the external electric field of the plant. It can be assumed that small drops mainly settle on the back side of the roots, where large drops are not able to get under the influence of inertial forces. If the static charge is removed from the walls of the aeroponic installation, then the effect of static electricity on the spray of the solution from the nozzles can be reduced by an order of magnitude. As a result of the absence of external polarization from the surfaces of the structure, it is possible to achieve a high efficiency of the distribution of the nutrient solution on the roots of plants.

According to the recommendations for different types of biologically active drugs and different cultures, the optimal size of drops when applied varies from 80 to 200 microns. Given a given range of droplet sizes, we can conclude that the data obtained meet the technological requirements.

**4. Conclusion**

1. The use of the electrostatic method of charging drops, in the aeroponic technology of growing potato mini-tubers, will increase the efficiency of applying the nutrient solution to the roots of the plant. With the help of the electrostatic method, the accuracy of the dosage of the nutrient solution increases, as well as the distribution of liquid drops with oxygen on the root system of plants located in the aeroponic box improves. In this case, the supply voltage of the ionizer must be at least 14 kV.
2. As a result of the effective distribution of fine droplets on the roots of plants, the consumption of the nutrient solution is reduced. Reduces the duration of operation and the frequency of switching on the pumps. This leads to less wear on the structural parts and slower clogging of the injectors.

3. It should be noted that with an increase in the voltage on the ionizer electrodes, the density of the coating with drops of the root system of the plant increases. This effect is especially pronounced on the back side and in the narrow areas of interweaving of root hairs. This is important to increase the number of mini-tubers formed on the roots of the potato plant.

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