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EFFECT OF CONTROLLED HYDRODYNAMIC CAVITATION IN IRRIGATION WATER ON THE GROWTH ENHANCEMENT OF SCOTS PINE SEEDLINGS

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Abstract

The purpose of the research was to study the effect of structured water on the growth of Scots pine seedlings. The article discusses the results of experimental irrigation with structured water of seedlings of scots pine. Biological and physical research methods were used, such as fixation of root system development and in-depth analysis of irrigation water. Some features of the intensification of the growth of seedlings associated with changes in the structural characteristics of irrigation water, based on the results of mass spectrometry and other analyses, have been identified. In particular, it is shown how, under the influence of hydrodynamic cavitation, an increase in the concentration of ions of various chemical elements appears in irrigation water, which can be considered as a fertilizer chelate. The effect of hydrodynamic cavitation on irrigation water leads to an intensification of the growth of seedlings of scots pine, an increase and proliferation of the root system. The development of the root system was recorded in dynamics and the fact of intensification of growth under the influence of cavitation was established. It should be noted that there is quite little data in the literature on the effect of cavitation on the structure of water, so this material will be a definite contribution to the development of this direction.

Keywords: Hydrodynamic cavitation, intensification of the growth, mass spectrometry, Pinus sylvestris, Chelated fertilizers, Structured water.

Aims.

The issues of drinking water quality, agricultural irrigation and irrigation are becoming more and more acute. The relevance and relevance of practical applications in the field of water preparation and treatment is beyond doubt. The boom in demand for nanotechnology, new technologies in various ways of structuring water, other liquids and solutions is growing exponentially.

The data from the materials of the International Committee on Water Resources at the UN, WHO and other generally recognized and specialized international expert organizations are well known that fresh and, especially, drinking water will become a strategic resource by 2025. Over the past decades, the increasing use of various types of mineral and organic fertilizers has led to an impressive increase in yields. The main emphasis in them was placed on the use of macronutrients - nitrogen, phosphorus and potash fertilizers. There is a large amount of fertilizers on the market. And every year their list is updated. Among this wide variety of fertilizers, it is proposed to choose highly environmentally friendly, produced on the basis of safe technologies, easily soluble and universal. Chelated forms of fertilizers differ favorably from fertilizers of the last generation, for example, inorganic metal salts in that they have a «milder» effect on plants and are immediately absorbed by them, and do not turn into insoluble compounds in the soil. Mineral salts, on the contrary, can be toxic to plants and are absorbed only by 20-30%. The remaining 70-80% are lost, and we are to have to apply more than the required amount of fertilizers, thereby harming the environment and your health.

The fact of the influence of hydrodynamic cavitation in the form of a thermodynamic effect is known [1], as well as changes in the structure of water when exposed to ultrasonic cavitation [2, 5]. It should be noted that there is quite little data in the literature on the effect of cavitation on the structure of water and other manifested properties that were studied in [3, 4]. The change in the properties of water when exposed to cavitation was also discussed in works. [5, 6, 7]. Work [8] is devoted to changing the structure of water and other solutions, in work [9] ultrasonic resonator arrays for implantation devices are proposed. It is also shown that the instantaneous collapse of cavitation cavities leads to the appearance of ultrasonic vibrations [10, 11]. The work [12] was devoted to a computational study on the change in the properties of water under the influence of cavitation. Cavitation leads to a change in the physicochemical properties of water, its partial ionization, since cavitation processes are accompanied by sonoluminescence during the formation and instant collapse of microbubbles. It was found that there are practically no or very few studies devoted to the effect of cavitation on irrigation water in order to intensify plant growth.

Methods.

The authors have been studying the effect of both ultrasonic cavitation [2] for the intensification of tomato growth and hydrodynamic cavitation for seedlings of scots pine for a long period. For irrigation and creating conditions for structuring irrigation water, a cavitation device was created [13], which made it possible to create controlled cavitation in the flow of irrigation water.

The cavitation device, made according to the type of Venturi tube with parabolic walls, at the exit from the confusor section of which profile twisting blades are installed, works as follows (Fig.1). The use of swirling blades having a streamlined profile allows the flow to be hydrodynamically formed, and in such a way that the vapor-gas phase in the form of microcaverns is formed throughout the volume of the diffuser section due to the twist and mixing impulse given to them, which allows the microcaverns to collapse (collapse) in the high-pressure region of the Venturi tube, thereby creating an active structuring of the flow and contributing to the effective mixing of the liquid. The parabolic walls of the Laval nozzle allow for better formation of the fluid flow. It should be noted that the flow in the cavitation device was calculated using a 3D model [14].

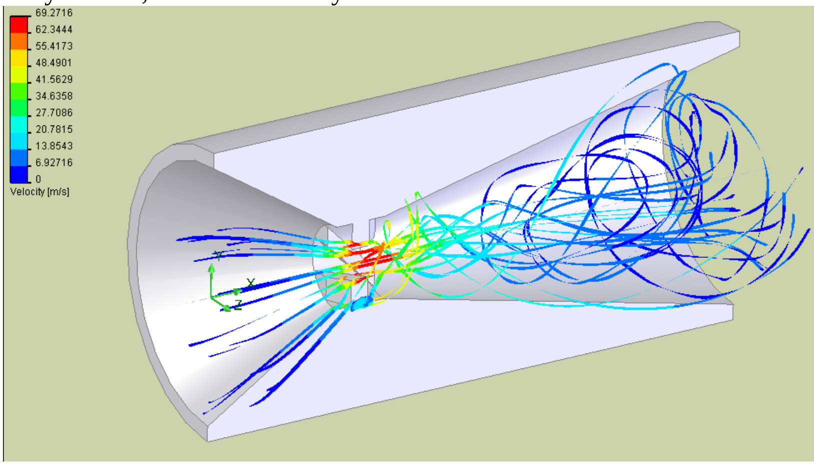

Fig. 1 The design of the cavitation device in a 3D model

An experimental nozzle (sprinkler) for watering pine seedlings, shown in Fig. 2, was made on a 3D printer, which was installed on a watering system in the open ground.


Fig. 2 The appearance of cavitation nozzles

A series of experiments was carried out on watering with structured and plain water seedlings of scots pine. To measure water samples, a MALVERN mass spectrometer was used, which determines 28 chemical elements, and a slight increase in pH values was recorded with a decrease in the measured electrical conductivity of water. The averaged results of fixing changes in the spectral analysis of water are shown in Fig. 3. It can be seen that the concentration of iron ions increases sharply with an increase in magnesium, boron, and copper ions. A sharp decrease in strontium ions is noticeable. Iron plays an important role in the formation of chlorophyll, being an integral part of enzymes involved in the synthesis of green pigment; regulates the processes of oxidation and reduction of complex organic compounds, is part of respiratory enzymes; with a lack of iron, the synthesis of growth substances is delayed. Copper is a part of enzymes, activates carbohydrate and protein metabolism. Signs of copper starvation are chlorosis of leaves, wilting and premature shedding of them. with a large deficit, growth is inhibited and the formation of fruit-bearing organs is disrupted.

Results

Experiments on growing Scots pine (Pinus silvestris) were carried out over several years on the territory of the forest nursery of the Laukar peasant farm.

Examination of seedlings for the presence and damage of pathogenic fungi and pest damage was carried out in the laboratory of the Semipalatinsk zonal forest seed station. In this case, the roots were washed in water, their length was measured, the number of sucking root endings was counted, and the presence of pathogenic microflora was determined.

The forest seedlings were healthy, without signs of mechanical damage, fungal diseases or damage by insect pests.

The results of the study of root systems are shown in Table 1.

Table 1.

Improving the characteristics of the root system.

Name	Root length, mm					
	Order 1		Order II		Order III	
	inspection	experience	inspection	experience	inspection	experience
Forest nursery	108	112	520	532	256	260

The length of the roots of Scots pine seedlings in the experiment increased by 5-12 mm compared to the control.

One of the main requirements when working with planting material is to prevent even slight drying of the root systems and their damage due to self-heating. After digging, normal water exchange in the plant is disrupted, and the root system is deprived of the ability to replenish even the minimum consumption of the required moisture. In addition, during the process of sorting, storage, transportation and planting, water loss by plants increases even more, which leads to the death, first of all, of small suction roots.

During this entire period, the root system of seedlings needs reliable protection from exposure to the sun, wind, high temperatures and other factors that contribute to desiccation. Planting material and its root systems are placed in liquid clay-humus mash, then the seedlings are buried in the snowfield previously prepared in winter before being transported to silvicultural areas. When preparing seedlings for planting, they are sorted and long roots are trimmed in accordance with the requirements of the standards. Before planting, the root systems are again placed in a mash, treated with biostimulants, and, if necessary, with pesticides to protect them from damage by root-gnawing pests.

When planting, the following requirements must be observed: carefully seal the root systems in the soil, avoid intertwining and bending of roots and voids around them, strictly maintain the established planting depth, straightness of the rows, which will ensure the possibility of mechanized soil care in forest crops.

In the spring, there is a mortality rate of pine seedlings caused by infectious lodging, in some years it is 50% or higher. There are known cases of complete death of all seedlings growing in the nursery.

Measures to combat lodging of seedlings consist of a set of preventive, exterminatory and agrotechnical recommendations.

Preventive measures include disinfection of soil, seeds and tires, but chemicals have a detrimental effect on the human respiratory system and are not removed from the soil for up to 10 years.

Seedlings and young pines are very sensitive to diseases caused by various fungi. In most cases, when the disease occurs, the affected plants die. The following diseases are especially dangerous for pine trees: lodging and damping off of seedlings, yellowing of needles, curvature of shoots.

Lodging of seedlings is a disease caused by fungi from the genus Fusarium, as well as fungi from the genera Pythium, Botrytis, Alternaria, etc. Pine seedlings up to 1-2 months old are affected by the disease. Externally, the disease manifests itself in the formation of a constriction near the root collar or below the subcotyledon. As a result, the affected seedling falls to the ground and gradually dies, with the seedlings wilting from the root to the top. At the same time, root rot begins. When a diseased seedling is pulled out of the soil, the peripheral part of the root is torn and its central part is exposed. In some cases, the fungus causes the death of seedlings even before they reach the surface. The death of seedlings older than 2 months of age due to lignification of the stem is not accompanied by lodging.

A good effect is achieved by temporarily reducing air and soil humidity, as well as frequently loosening the soil between lines. Experience in soil research using a cavitation system showed positive results (Table 2).

Table 2

Results of phytopathological examination

№	Substrate composition	*Alter-naria,%*		*Fusarium, %*		*Hormiscium ,%*		*Penicil-lium,%*		*Botrytis,%*		*Rhizo-pus,%*	
		exp -ce	cont rol	exp -ce	con trol	exp-ce	contr ol	exp-ce	cont rol	exp -ce	contr ol	exp -ce	con trol
1	Sandy soil, forest	1	4	0	1	1	5	3	11	2	5	1	7
2	Soil+sand+humus			1	6			2	8	0	4		
3	Sand+peat	0	2			1	4	1	6			0	2
4	Soil+humus			2	6			0	5			2	7
5	Soil+humus+sawdust	3	15	0	4	1	5	4	15	1	6		
6	Soil + humus layer	1	4	0	3	0	1	0	4				
7	Soil+loam	1	4					0	6	0	4		

According to the results of a study of soil samples, it can be concluded that by using cavitation technologies it is possible to avoid lodging of seedlings when growing them in open-ground nurseries.

The research carried out using a nozzle with a cavitation device made it possible to forget about this problem of seedling lodging, as the plants become resistant to diseases.

Laboratory results were obtained before and after the effect of cavitation on irrigation water. In Fig. Figure 3 presents a comparative description of the spectrograms.

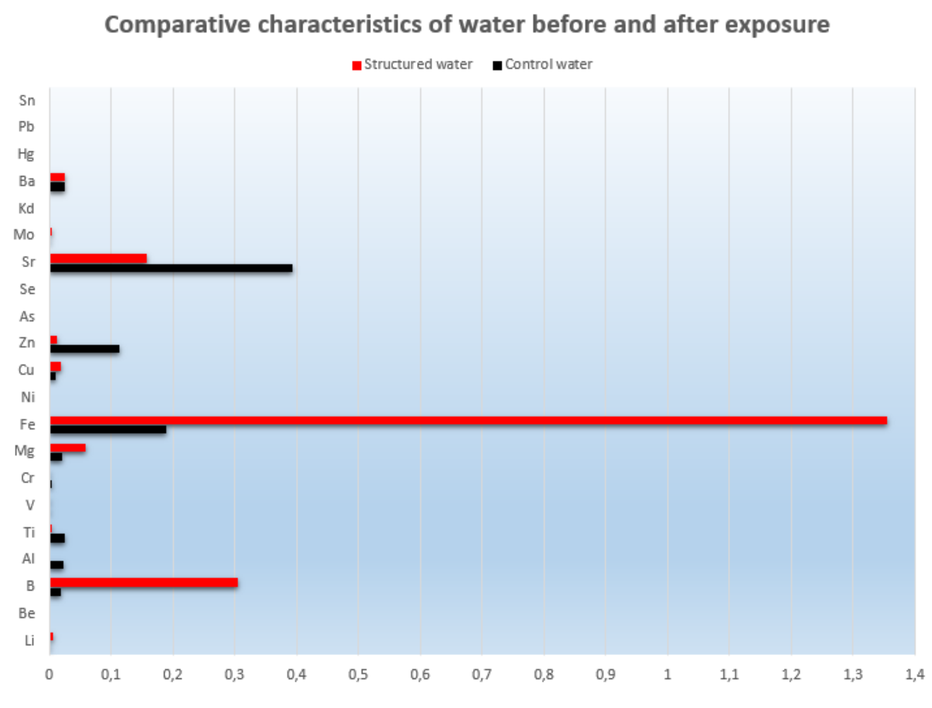

Fig.3 Comparative characteristics of spectrograms

Conclusions

The plant body, extracting substances in the form of microelements, creates their necessary concentration in its tissues, due to which it grows faster, is less susceptible to disease and also includes powerful stimulants for the growth of the root system - heteroauxins, which contributes to accelerated root formation.

In connection with the development of forest degradation processes in certain regions of Kazakhstan, the issues of growing healthy Scots pine seedlings to restore the Irtysh belt forests have been studied. Hydrodynamic cavitation can be generated via pressure fluctuations induced by varying the flow velocities of a liquid medium. It is achieved either by the passage of liquid through a constriction in a system, such as an orifice or venturi, or by the rotation of an object within liquid. Cavitation can be effectively induced by either ultrasound (acoustic cavitation, AC) or a local pressure drop (hydrodynamic cavitation, HC) Controlled hydrodynamic cavitation in irrigation water, specifically when used with a surfactant, can lead to a transient increase in leaf water potential in Scots pine seedlings, potentially impacting their growth and water dynamics. Further research on the effects of CHC on the microorganisms, nutrition contents, and safety and the optimizations of CHC devices and processes are needed in future.

Declaration

The authors would like to add that we completely exclude any conflict of interest. The research was carried out entirely on the initiative and at the authors' own expense as a great interest in the object of research. As authors, we can confirm once again that all the research was carried out at our own expense and without attracting any investments from outside.

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