NJD-iScience

№155

The Norwegian Journal of Development of the International Science

№155/2025

Norwegian Journal of development of the International Science

ISSN 3453-9875

It was established in November 2016 with support from the Norwegian Academy of Science.

DESCRIPTION

The Norwegian Journal of Development of the International Science, established in 2016 with support from the Norwegian Academy of Science, offers a platform for global researchers, academics, and students. Publishing 24 times annually, it covers current science topics. Submitting your article provides exposure to a diverse audience, enhancing your career. Our commitment to research and SEO ensures timely visibility. Submit to the Norwegian Journal of Development of the International Science today and join esteemed authors.

1000 copies

Norwegian Journal of development of the International Science

Iduns gate 4A, 0178, Oslo, Norway

email: publish@nor-ijournal.com

site: https://nor-ijournal.com

CONTENT

AGRICULTURAL SCIENCES

ARTS

CHEMICAL SCIENCES

ECONOMIC SCIENCES

MATHEMATICAL SCIENCES

PEDAGOGICAL SCIENCES

PHILOLOGICAL SCIENCES

PHYSICAL SCIENCES

TECHNICAL SCIENCES

AGRICULTURAL SCIENCES

EFFECTS OF THE ACOUSTIC RADIATIONS ON THE INTENSIFICATION OF PLANTS GROWTH

Dyussenov K.,
Eurasian National University named after L.N. Gumilyov
The Republic of Kazakhstan, Astana, Satpayev street, 2, 010008
Nedugov I.,
SMC-Kazakhstan Ltd
Sarzhanov D.
Academy of Public Administration under the President of the Republic of Kazakhstan,
Republic of Kazakhstan
https://doi.org/10.5281/zenodo.15298365

Abstract

The results of investigations of influence of acoustic radiation in the frequency range of 20 Hz and 50 kHz of some physical and chemical properties of irrigation water are represented. It is shown that range of ultrasonic radiation in a range close to 20 kHz is more effective for productive drip irrigation experienced plants which leads to increasing the concentration of dissolved trace metals in the irrigation water and also affects the change of pH suitable irrigation water. Two fixed frequencies in the studies were chosen to more clearly establish the fact of the occurrence of ultrasonic cavitation in irrigation water and were determined by the capabilities of the created device. The frequency of 20 kHz was chosen as the preferred one for fixing the increase in tomato yield by periodically weighing it and comparing it with the control irrigation line. Tomatoes were chosen as the most common greenhouse crop and a product often used in the diet.

Keywords: ultrasound, acoustic emission, cavitation, mass spectrometric analysis.

Introduction

A range of technical applications of hydrodynamic and ultrasonic cavitation rapidly increases in the world being directly used in medicine, naval applications, pharmaceutics, chemical technologies, cosmetics and cosmetology, etc. The energy of the collapse of microbubbles, at which the temperature reaches 6000°C, and the pressure of hydraulic microjets to 40 MPa causes ionization of water and aqueous solutions and is accompanied by many poorly studied processes.

Studies of the influence of hydrodynamic cavitation on the change in the physicochemical properties of aqueous solutions are devoted to the works (Loraine G. 2012, Mandar B. 2013) and purification of water, both from bacteria and other contaminants, and disinfection of water are shown in works (Al-Mahrouki A. 2012, Kuwabara M. 2005). Ultrasonic cavitation can also lead to a change in cellular structures, as shown in the work (Mojca and et al. 2014) and be used in cancer therapy. The phenomenon of hydrodynamic cavitation was also used to purify water from pharmaceutical contamination (Chuang YH and et al. 2010).

In addition, there are even studies confirming the effect of sound on plant growth, for example to positive effects on plant growth and resilience, sound alerts plants of potential danger and aids in defense. Sound guides plants towards essential resources, like water, through phonotropic root growth (Marie Liesbeth Demey and et al. 2023).

There is evidence that sonication using low frequencies of sound (as little as a few dozen Hz) to as high as ultrasound (several dozen kHz) may increase organogenesis (Jaime A. Teixeira da Silva and et al. 2014).

The fact of influence on growth and development of cellular structures and transport of various substances into cells under the influence of acoustic frequencies and cavitation of various spectrum is known (Riesz P. 1985, Hernández-García D. 2008). For example, the effects of ultrasonic acoustic emission were studied in works (Villanueva 2015, Pan Li 2015) and accompanied by cavitation on various structural characteristics of water, including some aspects of physical chemistry, and microbiological composition.

The publication (Heidi Appel, Reginald Cocroft 2023) states that progress in understanding the ecology and evolution of plant acoustic sensing requires testing how plants respond to acoustic features of their natural environments, using methods that precisely measure and reproduce the stimulus experienced by the plant.

The article (Andrea Nardini and et al. 2024) has obviously aroused new interest in the phenomenon of ultrasonic sound production by plants exposed to stress, especially drought.

This article presents new data on the effect of fixed ultrasound frequencies on the properties of irrigated water when watering one of the most common crops like tomatoes among many greenhouse plants. For the first time, the effect of ultrasound at 20 and 50 kHz on the physical and chemical properties of irrigated water and the intensity of tomato growth was studied. In some fragmentary Russian information on the effect of hydrodynamic cavitation on irrigation water, energy-intensive pumping equipment was used for irrigation in the open ground. And the authors decided to use ultrasonic exposure to irrigation water as more compact and relatively inexpensive.

Obviously, the use of hydrodynamic and ultrasonic cavitation is an example of nanotechnology and many aspects of such impact have been little studied.

The questions were extensively studied and the results of the influence of the infrasonic spectrum of oscillations on the growth of some cereal species are used.

The issues of water structurization under the influence of cavitation continue to be studied and are of interest in various fields, including crop production and agro technology.

We set the task to investigate the influence of a wide range of acoustic effects on irrigation water and, accordingly, the associated effects of intensification of the growth of vegetables and ornamental plants. The main purpose of this work was showing the results of our research and to show that there is a real possibility to obtain fertilizer chelate by ultrasonic action on irrigation water.

Materials and Methods

Two experimental plants for the generation of infrasound and ultrasound with subsequent transfer of momentum to the piezoelectric transducers were created (radiators) for this purpose. Generating unit consists of a pulse generator and a specially shaped frequency amplifying unit signal power and the control panel.

The direct impact on the water is carried in the radiation unit via piezoelectric transducers (Dyussenov K. 2012) (Fig. 1 - the device for generating infrasound and ultrasound). The frequency spectrum of emission before and after the experiments on the influence of irrigation with acoustic oscillations was recorded using a broadband oscilloscope brand VALLEMAN PC SGU250 and made adjustment range from 20 - 50 Hz on the first unit and 20 - 50 kHz per second.

The experiments were carried out from the beginning of spring to the end of October previous year on the basis of experimental greenhouses with polycarbonate cover for the cultivation of tomato (*Lycopersicon esculentum Mill*) size 6x3x12 m, located in the suburb of Pavlodar (Kazakhstan).

Water was supplied by the system of drip irrigation GARDENA (Germany): drip irrigation of 100 plants was carried through a hose branch from local wells, and the second, with the same water, after passing through the intermediate container with piezoelectric transducers and the last 100 plants were watered from a watering can or hose, i.e. without the use of drip irrigation. Both hybrids of tomato (*Lycopersicon esculentum Mill*) F1 resistant to diseases TMV Va Fol (Master, Rosemary) and varieties that are affected Phytophthora, Fusarium and TMV (Bon appetite, raspberry cream, Budyonovka and Gold dome) were used in the experiment. The construction of the container with two piezoelectric transducers immersed in it, treated with sealant, to avoid corrosion, represented a channel of specially designed forms for organizing the flow turbulence to obtain the best effect of mixing the flow of water.

During experiments once every 5 - 6 days, water samples were taken for measurement of pH and mass spectrometric analysis. pH - metry was performed on a laboratory basis of the Eurasian National University named after L. Gumilyov with overlapping pH measurements based on central laboratory of JSC "Kazakhstan Aluminum" combined with mass spectrometric analysis on the equipment of the company MALVERN (United Kingdom), allowing measurement of 28 chemical elements. Laboratory equipment has local and international metrological certification. As a result of investigations the following facts were established.

Results and Discussion

The frequency spectrum of the radiation in the range 20-50 Hz virtually did not affect the pH of irrigation water. The most characteristic effects on the structure of irrigation water at 20 Hz manifested in increasing cadmium concentration by almost 92% zinc and almost 7 times. As seen from the integrating spectrograms where abscissa mg dm^{-3} drawn on generalized results of analyzes of samples (Fig. 2, 3) with a sharp increase in the concentration of cadmium Cd (about 4 times), and tin Sn (by 11 times) the remaining group trace metals have remained virtually unchanged.

At the same time, the content is within the MPC as the EU countries and the United States, Russia and the MAC recommended by WHO. For example, MPC WHO compared with the data obtained are shown in Table (Table. 1).

Irrigation water treated with 20 Hz resulted in a strong inhibition of plants, after 6-7 irrigations to disease TMV plants (tobacco mosaic virus), but after changing the frequency of the acoustic oscillations at 50 Hz growth and development of plants recovered after 5 irrigations. The highest efficiency of irrigation water gave exposed to ultrasound in a range close to 20 kHz, the second pilot unit. Results of averaged spectrograms in mg/dm^3 (Fig. 4 - 5) show that a pronounced positive effect on the growth of tomato at a frequency range of 20 kHz the radiation had growth of concentration iron of 22%, copper Cu in 1,6 times and manganese Mn by 8 times.

It is possible that the increase in yield recorded when weighing tomatoes for experimental (that is, when watering water exposed to ultrasound) and control (when providing irrigation with ordinary water) is caused, as one of the reasons, by the activation of trace elements and the appearance of heteroauxins that activate the development of the root system of tomatoes. The cluster structure of irrigation water is also important, changing its structure, which requires further research.

After irrigation with irrigated water under the influence of ultrasonic radiation of 50 kHz, there was no increase in yield relative to the frequency of exposure of 20 kHz.

Thus, minor, an average of 1.14 - 2.01% grew acidity (pH) of the treated water for irrigation at 20 kHz and at a frequency of 50 kHz pH values increased to 3.28%. Analysis of the spectrograms and measurement of irrigation water pH after ultrasonic treatment led to the conclusion that the water gets new properties related to its partial ionization leading to changes in its molecular structure.

By collecting fruit, tomatoes (*Lycopersicon esculentum Mill*) treated with structured water, ahead of the growth rates of tomato bushes, which are watered with plain water. 285 kg of tomatoes were obtained from the

experimental plants and only 243 kg from controlled ones for the whole period of the experimental irrigation. At the same time 6-7 irrigations produced at a frequency of 20 kHz is allowed to increase the yield by 58-62%. Plants watered with structured water in October had a new brush, bloom, i.e. did not feel the onset of fall, and the control plants the leaves turned yellow, most of them died.

In the Fig. 6 a portion of the results of experiments is shown.

It can be seen that a number of tomato (*Lycopersicon esculentum Mill*) on the left, watered with plain water has ceased to exist and the right lane, when watering with water treated by ultrasound continues its rapid growth and fruiting.

In the Botanical garden of Odessa University the effect of ultrasound on the possibility of accelerating the rooting and increase the yield of rooted cuttings of roses (Rosa L.) were studied. Cuttings are cut from the middle of the annual semi lignified shoots. Related bunched cuttings were placed in a bath, the bottom of which served as a radiating plate, after which the tub was filled with water. Experimental cuttings were sounded 15, 30, 45 seconds, 1, 3, 5, 12 and 20 minutes at an intensity of 1 W cm^{-2}, and an oscillation frequency of 22 kHz, the controlled ones were kept in an aqueous environment. For rooting, a mixture of leaf soil, humus and river sand were used in the ratio 2:2:1. The test results showed that all varieties of treatment for three minutes increases the rooting and accelerates root formation. Rooting time in the experiment was 15 days, 28 days in the control.

In the greenhouse, the authors also made an experience in fixing the rate of rooting roses (Rosa L.), and the period was chosen when any plants rooted very badly - a period of late summer. Cuttings were rooted in the calcined garden ground. In the experiment - planting the soil was watered with structured water, then, at an angle of 45 degrees, cuttings with three buds were planted (03.08.2018). Control ones were cut into the soil, watered with plain water. The result exceeded all expectations - the root system of the prototype in the past month has formed well, control plants only the beginnings of roots formed during this period.

Land escape of a rose (Rosa L.), watered with structured water has a length of 4 cm, the roses (Rosa L.) with a simple watering 2 -2.5 cm. It is safe to conclude that water passed sonication in a range close to 20 kHz is accelerator plant growth and development. At the same time, the specified frequency range of ultrasonic treatment prevents premature aging plants and increases their resistance to disease and the impact of other external adverse factors.

A number of works are known, among them (Amira Mohamed Abd El-Sattar and et al. 2022), the effect of ultrasonic exposure period on germination and early seedling behaviors of fenugreek seeds under salt stress was investigated in a laboratory experiment.

Ultrasonication may alter plant growth and development (Anita Kiraly and et al. 2025), and an increasing number of studies are being carried out to investigate its effects on both in vitro plant culture and greenhouse or field plant production, as well as on the biochemical and molecular functions of plants.

It is quite obvious that ultrasonic and hydrodynamic cavitation has a rather complex mechanism of affecting water and aqueous solutions and is manifested in many physical and chemical aspects. Mass spectrometric analysis of irrigation water allowed to illustrate that partial ionization of irrigation water occurs with activation of metal ions dissolved in it.

Research on the effects of sound on plant growth has been studied (Ratnesh Chandra Mishra & Hanhong Bae, 2019) and it has been found that plants' sensitivity towards sound has started gaining attention only recently. The influence of sound vibrations on biology was discussed in a paper (Alexis M. Kollasch and et al. 2020) where various effects were identified.

It is possible that this factor as one of many can cause activation of plant growth, accelerates and enhances cellular metabolism.

In all probability, the activated metal ions, the concentration of some of which increased several times in the form that ultrasonic cavitation caused, greatly improve and intensify plant growth and appear as one of the factors contributing to this.

Conclusion

It is possible to conclude with high confidence that the different spectra using ultrasonic radiation can be in one way or another affect the physicochemical properties of water. This is confirmed by the experiments. Against the background of the primary results of the spectra of acoustic vibrations produced by irrigation water to 20 kHz (increasing the total yield of 15% after 7-8 drip irrigation, about 13-18 days) is likely to predict the intensification of the growth of terrestrial vegetables and obviously increase their productivity (fixed increase fruit size by 50-95%).

It is possible to draw a conclusion about the existing mechanism of interrelation of microbiological and physicochemical processes caused by the effect of cavitation on irrigated water for greenhouse growing tomatoes and cuttings of roses with a fixed effect on irrigation water of ultrasonic frequency spectrum from 16 to 24 kHz. Comparative testing and testing of both stems and leaves, and the root system of tomatoes revealed an increase in the green mass and increased development of plant roots. Thus, a direct link was established between the direct effects of increasing the concentration of trace elements of various metals, provoking to some extent the activation of plant growth without the introduction of special fertilizers.

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.

References:

1. Al-Mahrouki A.A., Karshafian R., Giles A., Czarnota G.J. 2012. Bioeffects of ultrasound-stimulated microbubbles on endothelial cells: Gene expression changes associated with radiation enhancement in vitro, Ultrasound Med Biol. Volume 38, P. 1958–1969.

2. Chuang YH, Cheng PW, Chen SC, Ruan JL, Li PC. 2010. Effects of ultrasound-induced inertial cav-

itation on enzymatic thrombolysis, Department of Electrical Engineering, National Taiwan University, Taipei, Taiwan. Ultrason Imaging. Apr. 32(2), P. 81-90.

3. Marie Liesbeth Demey, Ratnesh Chandra Mishra, Dominique Van Der Straeten. Jul 2023. Sound perception in plants: from ecological significance to molecular understanding, Volume 28, Issue 7 P. 731-856,

4. Jaime A. Teixeira da Silva, Judit Dobránszki 2014. Sonication and ultrasound: Impact on plant growth and development. Plant Cell Tissue and Organ Culture 117 (2): P. 131-143.

5. Heidi Appel, Reginald Cocroft. July 2023. Plant ecoacoustics: a sensory ecology approach, Trends in Ecology & Evolution, Volume 38, Issue 7 P. 623-630.

6. Andrea Nardini, Hervé Cochard, Stefan Mayr, June 2024. Talk is cheap: rediscovering sounds made by plants, Trends in Plant Science, Volume 29, Issue 6, P. 662-667.

7. Dyussenov K., Nedugov I. Cavitation energy converter: Patent Provisional Application, USA, Number: 61745772 from 25.12.12 P. 1-21.

8. Dyussenov K.M.,Sakipov, K.E., Shayakhmetova, R.T., Nedugov, I.A. Aitmagambetova M.B., Yessimseit, A.K. Influence of the impact of acoustic cavitation on the physical and chemical properties of water. Eurasian Physical Technical Journal, 2021, 18(1), pp. 65–69.

9. Hernández-García D., Castro-Obregón S., Gómez-López S., Valencia C., Covarrubias L. 2008. Cell death activation during cavitation of embryoid bodies is mediated by hydrogen peroxide, Experimental Cell Research, Volume 314, Issue 10, June, P. 2090–2099.

10. Kuwabara Mamoru, Yo Ken, Kubo Takashi. 2005. Sono-processing of materials based on an acoustic cavitation phenomenon, Journal of Current Advances in Materials and Processes, Volume 18, № 4, P. 962-969,

11. Loraine G., Chahine G., Hsiao C.T., Choi J.K., Aley P. 2012. Disinfection of gram-negative and gram-positive bacteria using DynaJets® hydrodynamic cavitating jets, Ultrason Sonochemistry, Volume 19(3), P. 710-715.

12. Mandar Badve, Parag Gogate, Aniruddha Pandit, Levent Csoka. 2013. Hydrodynamic cavitation as a novel approach for wastewater treatment in wood finishing industry, Separation and Purification Technology, Volume 106, P. 15-21.

13. Amira Mohamed Abd El-Sattar, Eman Tawfik. 2022. Effects of ultrasonic waves on seedling growth, biochemical constituents, genetic stability of fenugreek (Trigonella foenum-graecum) under salinity stress, Vegetos (2023), V 36, P. 1427–1436.

14. Mojca Zupanc, Tina Kosjek, Martin Petkovšek, Matevž Dular, Boris Kompare, Brane Širok, Marjeta Stražar, Ester Heath. 2014. Shear-induced hydrodynamic cavitation as a tool for pharmaceutical micropollutants removal from urban wastewater, Ultrasonics Sonochemistry, Volume 21, Issue 3, P. 1213-1221.

15. Pan Li, Yuan Song, Shuili Yu, Hee-Deung Park. 2015. The effect of hydrodynamic cavitation on Microcystis aeruginosa: Physical and chemical factors. Chemosphere, Volume 136, P. 245-251.

16. Riesz P., Berdahl D., Christman C.L. 1985. Free radical generation by ultrasound in aqueous and nonaqueous solutions, Environ Health Perspective, December: 64, P. 233–252.

17. Anita Kiraly, Dora Farkas, Judit Dobránszki. 2025. Ultrasound in Plant Life and Its Application Perspectives in Horticulture and Agriculture, Horticulturae, 11(3), P. 318-323.

18. Ratnesh Chandra Mishra & Hanhong Bae, 2019. Plant Cognition: Ability to Perceive ‘Touch’ and ‘Sound’, Sensory Biology of Plants, Springer, Singapore., p 137–162.

19. Alexis M. Kollasch, Abdul-Rahman Abdul-Kafi, Mélanie J. A. Body, Carlos F. Pinto, Heidi M. Appel, Reginald B. Cocroft, 2020. Leaf vibrations produced by chewing provide a consistent acoustic target for plant recognition of herbivores, Oecologia Volume 194, pages 1–13.

20. Villanueva M.V., Luna M.C., Gil M.I., Allende A.. 2015. Ultrasound treatments improve the microbiological quality of water reservoirs used for the irrigation of fresh produce. Food research international, Volume 75, P. 140-147.

Table 1.
The comparative characteristics of the content of trace minerals

MAC (WHO) mg/dm^3	After influence 20 kHz mg/dm^3	After influence 50 kHz mg/dm^3
Cu 0.20	0.14	0.136
Zn 0.30	0.231	0.148
Cd 0.003	0.00039	0.00011

Fig. 1. *The device for generating infrasound and ultrasound*

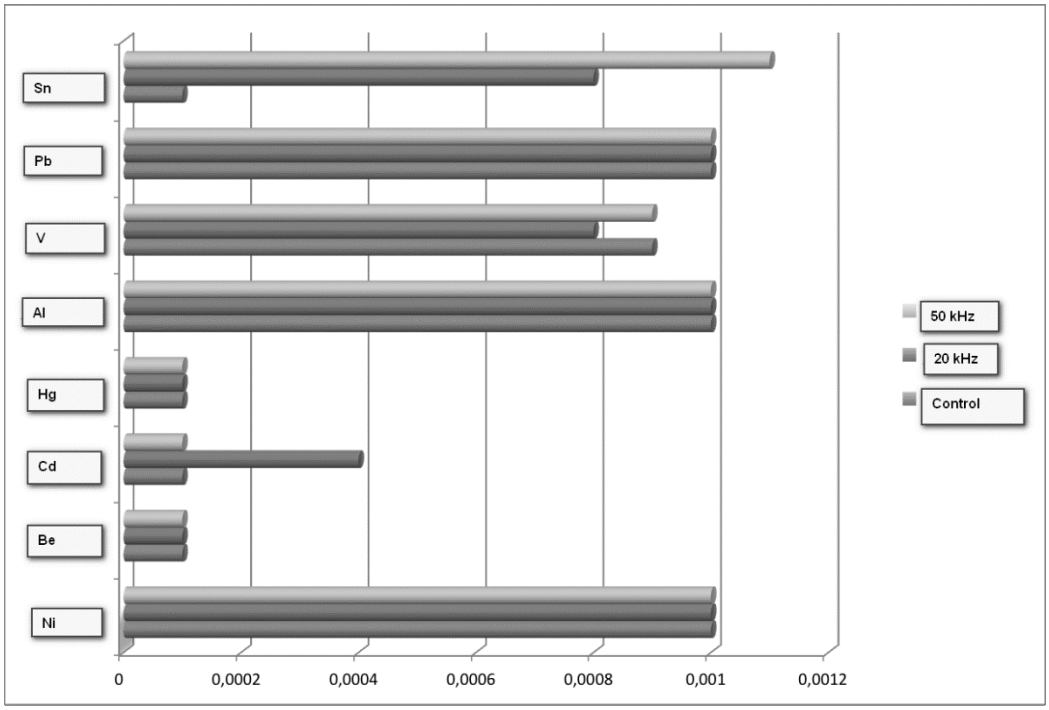

Fig. 2. *The increasing of Sn and Cd concentration in water after ultrasound influence*

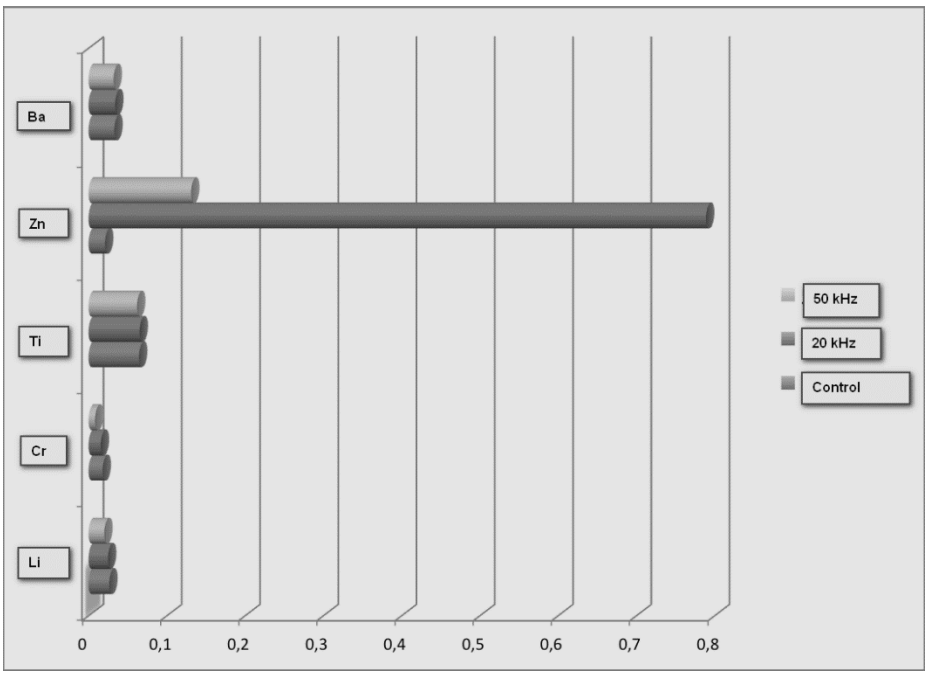

Fig. 3. *The increasing of Zn concentration in water after ultrasound influence*

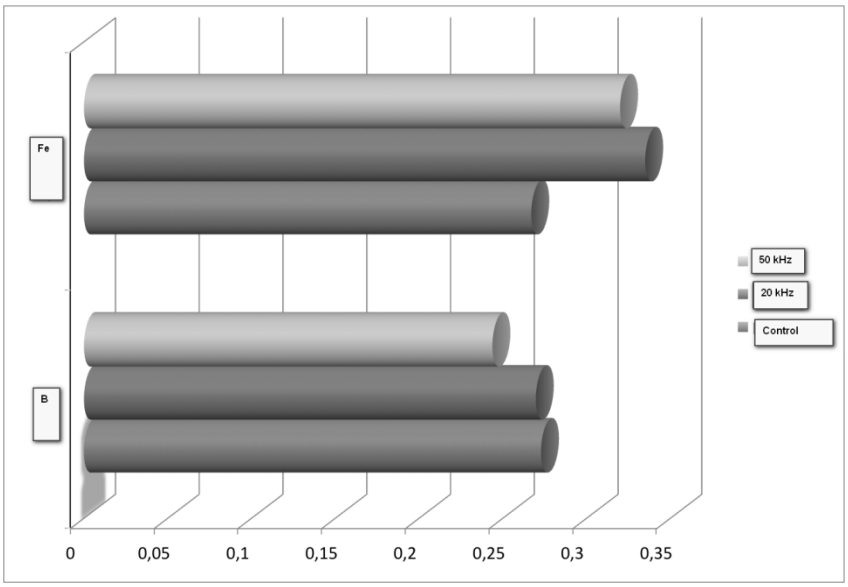

Fig. 4. *The increasing of Fe concentration in water after ultrasound influence*

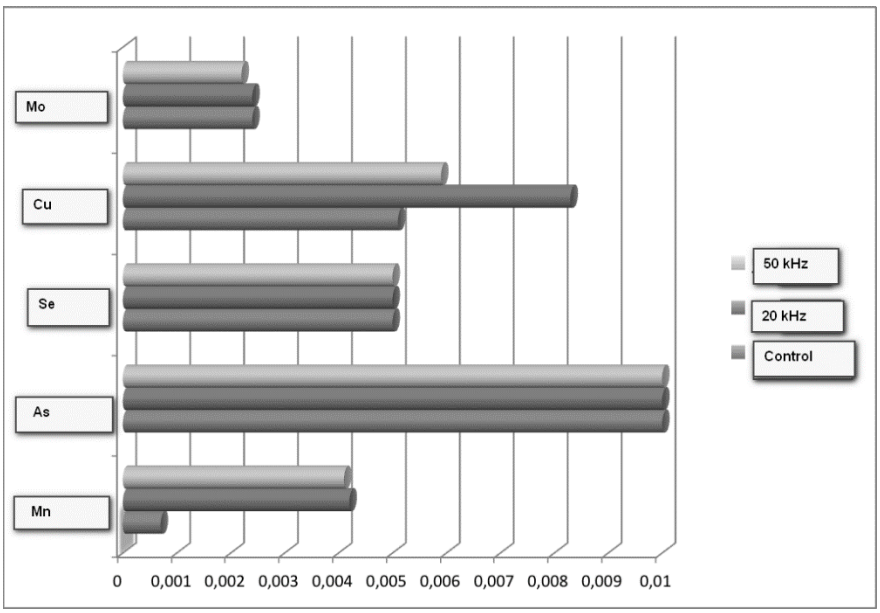

Fig. 5. *The increasing of Cu and Mn concentration in water after ultrasound influence*

Fig. 6. *The comparison of the intensity of tomato growth with the action of ultrasound on water and without it*