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Study on the effect of the use of quantum structured water on the microbial activity and taxonomical composition of the rhizosphere communities in tomatoes and eggplant cultures in an unconventional system

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Abstract Water is the most widespread chemical combination, both in nature and in the human body, having the most important role in the development of all biochemical reactions. In Europe, but also in the world, over a third of water is used in the agricultural sector. That is why solutions are being sought to reduce water consumption in horticulture, especially for soilless crops. Water efficiency is very important for farmers. In the present study, research was carried out to evaluate the influence of quantum structured water (QSW) on the number of microbes and the taxonomic composition of eggplant rhizosphere communities. Two species, tomato, and eggplant, from the same botanical family, cultivated in an unconventional system, on a perlite substrate, were studied. Water from the greenhouse source and water from the greenhouse source but quantum structured were used for comparison. It was found that, although the prepared nutrient solution presented the same composition, in the case of the use of quantum structured water, the conditions at the level of the root system, were much more favorable for increasing the counts of bacterial and fungal species.

Key words

quantum structured water, tomatoes, eggplants, microbial antagonists, biocontrol, soilless

Domenico (2020) states that one of the characteristics of structured water is to position the individual molecules that compose it in a precise order, noting at the same time, that this positioning generates a structure that allows for greater storage of information.

Dubey et al. (2018) mention that structured water can also be used to irrigate agricultural crops with very high benefits, by improving the quality and quantity of production. It is also mentioned, based on the studies carried out, that the structured water does not contain toxins, contributes to better oxygenation and regulates and balances the minerals of the soil.

In recent years, against the background of the development of the concepts of structured water use in human consumption, with obvious effects on the body, it is necessary to reconsider the quality of water and its use in horticultural practice as well. Water is found in the content of plants in a percentage of over 80%, and in some species, for example in cucumbers, in a percentage of 99%, this being the binder of all biochemical processes in the body and from here, we can deduce the necessary daily amount and thus, the special importance of its quality.

Another aspect of the concept of structured water is closely related to the concept of "water memory". Water has the property of memorizing the properties of substances dissolved in it, even if they are in minimal concentrations.

Material and Method

Emoto (2007) argues that the "memory of water" theory includes the assumption that water "remembers" the properties of a substance dissolved in it, even if the concentration of the substance is zero. This fact aligns the horticultural production in our country with the directives of the European Community regarding the reduction of environmental pollution as a result of horticultural practices, it being known that the horticultural system involves extremely intensive culture technologies that, not infrequently, endanger the integrity but also food security.

Lavrnić et al. (2017) estimated that EU countries are expected to face very acute water stress in the coming future, leading to a major negative impact for agricultural crops.

Protected crops make it possible to effectively optimize the water used for irrigation, especially in the soilless culture system [22].

Saikat and Rupa (2022), point out that the use of structured water brings important benefits if it is used to irrigate crops. Thus, the authors emphasize the properties of magnetized structured water, that the normal tetrahedral structure of water is modified into a hexagonal shape. This shows that the chemical formula of structured water is H_3O_2 compared to that of unstructured water, normal H_2O. They appreciate that structured water reduces salinity, which allows farmers to use this water because it has better characteristics, at the same time, consumption is reduced by about 20-30% and plants improve their yields.

Ali et al. (2014), mention the benefits of using magnetized structured water on the growth and development of plants, starting from the better germination of seeds, an aspect also noted by Amaya et al. (1996) but also to the production of seedlings, the author proving greater heights and leaves with a larger surface area.

Improved water performance was also noted by Duarte et al. (1997), who used magnetically treated water with a magnetic device in the range of 3.5-136 mT and found an increase in pea production of up to 13%.

Other studies have shown that using magnetized water, plant roots show more vigorous growth [15; 10].

The research aimed at testing the effect of using quantum structured water on the growth, development and productivity of different horticultural species, with a view to recommending it to horticultural producers in Romania, as a method of rational use of water and at the same time improving cultivation technologies that ensure production of quality in food safety conditions. Research has been carried out to assess the influence of activated (structured) water on the microbial counts and taxonomic composition of communities in the rhizosphere of eggplants and tomatoes.

The biological material used was represented by plants of tomato, variety 'Flaviola', and eggplant, cultivar 'Favorite' F_1 and 'Claudia' F_1 grown in soilless system on perlite substrate in the greenhouse within the Research Center for Studies of Food Quality and Agricultural Products, U.A.S.V.M. Bucharest.

The experimental variants were the following:

V1 - tomato 'Flaviola', quantum structured water and chemical fertilizer (1);

V2 - tomato 'Flaviola', chemical fertilizer – control (2);

V3 - eggplant cultivar 'Favorite' F_1, chemical fertilizer – control (3);

V4 - eggplant cultivar 'Favorite' F_1, quantum structured water and chemical fertilizer (4);

V5 - eggplant cultivar 'Claudia' F_1, chemical fertilizer - control (5);

V6 - eggplant cultivar 'Claudia' F_1, quantum structured water and chemical fertilizer (6).

The seedlings were produced in the research greenhouse, and at planting they were 35 days old. The planting was carried out on mattresses filled with perlite, with a length of 1 m. On each mattress, 2 plants were planted at a distance of 40 cm. Fertilization was carried out daily starting at 8 o'clock, every 30 minutes with 200 ml of nutrient solution/watering until 5 o'clock. In the first part of vegetative growth, the amount of nutrient solution distributed per day was 1.5 l, then the amount it reached 3.5 l/plant during the intense fruiting period. The EC of the nutrient solution was in the first week 1.5 mS, and the pH 5.5. Depending on the phenophase, the EC of the nutrient solution gradually increased but the pH remained constant. During the vegetation period, the temperature values were recorded in the greenhouse but also in the perlite substrate.

Microbiological parameters represented by total counts of heterotrophic aerobic bacteria (cultivated on Nutrient Agar medium), total counts of fungi (cultivated on Potato Dextrose Agar medium) were estimated according to soil dilution method and reported to 1g dry soil.

Stapp culture medium overlayed with filter paper was used for assessing the cellulolytic capabilities of microorganisms.

Taxonomic identification of microorganisms developed on culture media after incubation in the dark at 25°C was done on the basis of cultural, morphologic / physiologic characteristics, according to determinative manuals for bacteria [6; 8; 23] for fungi.

Results and Discussions

The temperatures in the greenhouse, although they were programmed according to the requirements of the cultivated species, tomatoes and eggplants, on some days, between 12 and 3 p.m., when the solar intensity was high, the temperature in the greenhouse increased, reaching values of 32.55°C at the end in May, and even 38.44°C in mid-June. During the night, temperatures fluctuated between 17°C and 19.7°C. Figure 1 shows the minimum temperature values during the night and the maximum during the day.

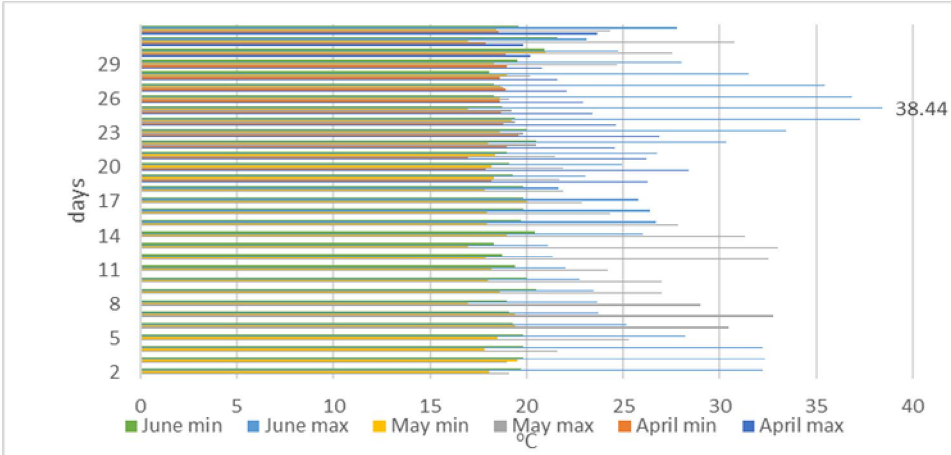


Figure 1. Maximum and minimum temperatures in the greenhouse

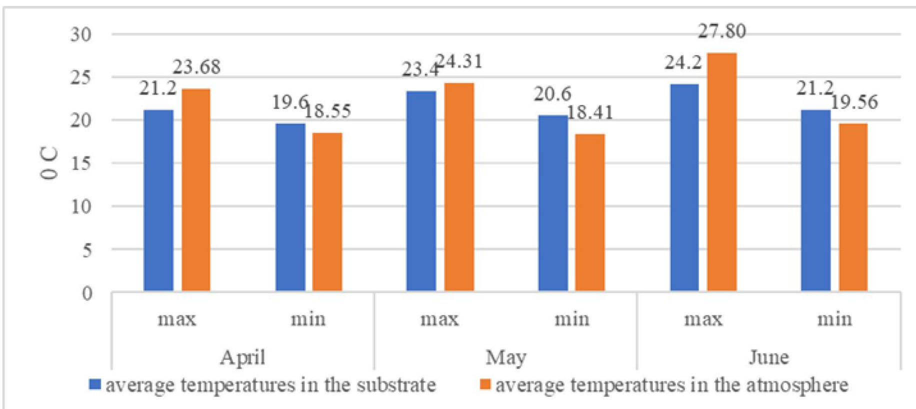


Figure 2. Average maximum and minimum temperatures in the substrate and in the greenhouse

The Figure 2 shows the average temperature data from the atmosphere, from the greenhouse, from the culture period and from the culture substrate. In April, average temperature values of 21.2°C were recorded in the culture substrate and 23.68°C in the greenhouse. In May, maximum values of 23.4°C and 24.31°C were recorded in the culture medium. The minimum temperatures in the culture substrate were 20.6°C and those in the atmosphere 18.41°C during the night.

In June, the average temperature values in the substrate were 24.2°C and in the atmosphere in the greenhouse 27.8°C. Temperatures in the substrate were 21.2°C and in the greenhouse 19.56°C during the night. It should be noted that the average temperatures in the substrate were higher during the night compared to those in the atmosphere.

The general aspect of the tomato culture is presented in figure 3*a* as well as of the eggplant culture for variants 1 and 2.

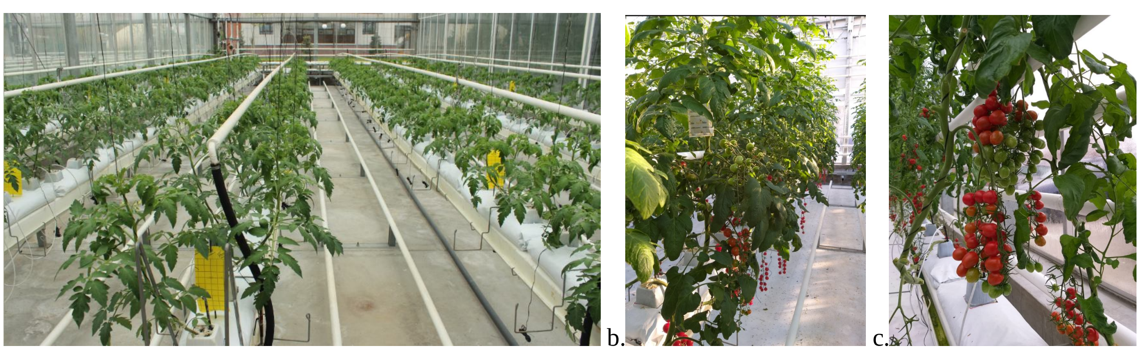
a.  b. c.

Figure 3. The general appearance of the tomato crop during the growing season (a); V1 'Flaviola' cultivar- treatment with quantum structured water and chemical fertilizer (c) and V2, 'Flaviola' cultivar chemical fertilizer – control (d)

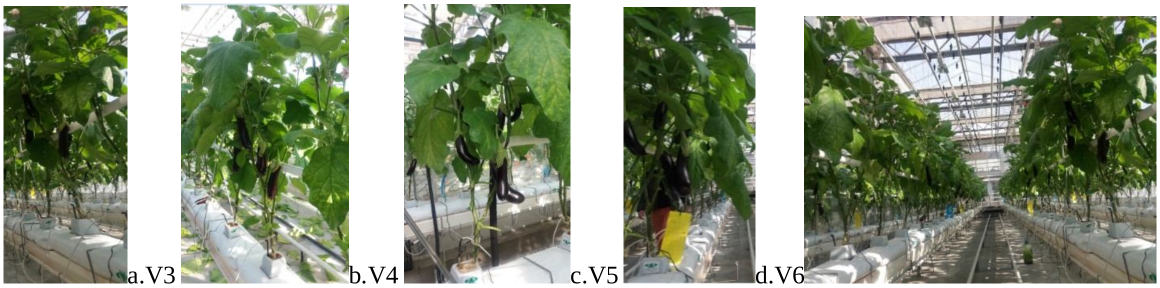


Figure 4. Appearance of the eggplant crop during fruiting on variants: a. V3; b. V4; c. V5; d. V5 and the general e-aspect from culture

The microbial counts and the taxonomic composition of the bacterial and fungal microflora in the substrate samples (represented by perlite) from the rhizosphere zone of tomato and eggplant plants, were determined to highlight the influence of quantum structured water compared to non-activated water. The densities of aerobic heterotrophic bacteria in the analyzed samples were in the category of low values in samples from V1-V5 and moderate in sample V6 (Eggplant 'Claudia' F_1 quantum structured water + chemical fertilizer) (Table 1).

The fungal microflora developed with numerically reduced counts in the variants watered with water and with moderate counts in those with energized water, high densities being observed in sample V6 (Eggplant 'Claudia' F_1 quantum structured water + chemical fertilizer), this being the most populated with both types of microorganisms (Table 1).

Table 1. Microbial counts of bacteria and fungi in experimental variants

Var. no.	Experimental variants	Bacterial counts *x 10^6 viable cells x g^{-1} dry soil*	Fungal counts *x 10^3cfu x g^{-1} dry soil*
V1	tomato 'Flaviola', quantum structured water and chemical fertilizer	2.713	78.529
V2	tomato 'Flaviola', chemical fertilizer – control	1.878	48.939
V3	eggplant cultivar 'Favorite' F_1, chemical fertilizer – control	2.133	34.925
V4	eggplant cultivar 'Favorite' F_1, quantum structured water and chemical fertilizer	5.876	67.459
V5	eggplant cultivar 'Claudia' F_1, chemical fertilizer - control	2.391	38.968
V6	eggplant cultivar 'Claudia' F_1, quantum structured water and chemical fertilizer	12.832	180.100

From a qualitative point of view, quantum structured water stimulated the specific diversity of the group of aerobic heterotrophic bacteria compared to non-activated water, the highest number of species being recorded in sample V4 (Eggplant 'Favorite' F_1, quantum structured water and chemical fertilizer).

The analysis of the taxonomic composition of the microbial communities in the samples showed a low specific diversity (1-2 species) for the fungal communities and moderate (3-6 species) for the bacterial ones (Table 2).

Table 2. Taxonomic composition of bacterial and fungal microflora in experimental variants

Var. no.	Experimental variants	Bacterial species (Nutrient Agar)	Fungal species/cellulolytic microflora (PDA/Stapp)
V1	tomato 'Flaviola', quantum structured water and chemical fertilizer	*Pseudomonas fluorescens, Bacillus megaterium, Bacillus circulans*	*Trichoderma viride,* white sterile mycelia
V2	tomato 'Flaviola', chemical fertilizer – control	*Bacillus circulans, Bacillus megaterium, Pseudomonas fluorescens*	*Trichoderma viride*
V3	eggplant cultivar 'Favorite' F_1, chemical fertilizer – control	*Bacillus megaterium, Pseudomonas fluorescens, Arthrobacter globiformis*	*Trichoderma viride*

Table 2 (continuation). Taxonomic composition of bacterial and fungal microflora in experimental variants

Var. no.	Experimental variants	Bacterial species (Nutrient Agar)	Fungal species/cellulolytic microflora (PDA/Stapp)
V4	eggplant cultivar 'Favorite' F_1, quantum structured water and chemical fertilizer	*Pseudomonas fluorescens, Bacillus megaterium, Bacillus cereus, Paenibacillus dendritiformis, Bacillus subtilis, Micrococcus sp.*	*Trichoderma viride, Fusarium oxysporum*
V5	eggplant cultivar 'Claudia' F_1, chemical fertilizer - control	*Pseudomonas fluorescens, Pseudomonas aurantiaca, Micrococcus sp.*	*Trichoderma viride, Fusarium culmorum*
V6	eggplant cultivar 'Claudia' F_1, quantum structured water and chemical fertilizer	*Pseudomonas fluorescens, Paenibacillus dendritiformis, Micrococcus sp.*	*Trichoderma viride, Fusarium oxysporum*

Species identified in samples belonged to the genus *Trichoderma* (Figure 5), which tolerate well the acidic environments. Fungal species of the genus *Fusarium* potentially phytopathogenic (*Fusarium culmorum*) were identified in sample V5 with non-activated water and antagonistic *Fusarium oxysporum*, in samples from V4 and V6, with activated (quantum structured water), for both eggplant cultivars.

Bacterial communities, especially in the variants with quantum structured water, were dominated by fluorescent representatives of the genus *Pseudomonas*, bacilli and *Arthrobacter* species. The higher diversity of bacteria and the lower diversity of fungi are noted.

Figure 5. Fungal microflora in experimental variants V1-V6 (PDA medium, 4 days)

Our previous research (Enache et al., 2019) evidenced significantly higher root mass, foliar surface and total plant biomass accumulation for treatments with structured water. The development of antagonistic species of bacteria (pseudomonads) and fungi (*Trichoderma*, *Paecilomyces*) was noticed in cucumber, tomato and basil plants rhizosphere under the influence of structured water as compared with control variant watered with tap water.

Matei et al., (2016) evidenced a mechanism of biochemical antagonism against pathogens and hiperparasitism for *Trichoderma* isolates from soil.

Results from the present research are in concordance with other data from literature reporting the role of microbial antagonists belonging to the fluorescent pseudomonads [4; 19] or fungal strains of *Trichoderma* or *Fusarium oxysporum* [24; 7; 21; 17; 18].

Conclusions

The densities of aerobic heterotrophic bacteria in the analyzed samples were in the category of low values in variants V1-V5 and moderate in V6

(Eggplant 'Claudia' F_1, quantum structured water and chemical fertilizer).

The fungal microflora developed with numerically reduced counts in the variants watered with non-activated water and with moderate counts in those with energized water, high densities being observed in V6 (Eggplant 'Claudia' F_1, quantum structured water and chemical fertilizer).

From a qualitative point of view, quantum structured water stimulated the specific diversity of the group of aerobic heterotrophic bacteria compared to non-activated water, the highest number of species being recorded in variant V4 (Eggplant 'Favorite' F_1, quantum structured water and fertilizer).

Bacterial communities, especially in the energized water variants, were dominated by fluorescent representatives of the genus *Pseudomonas*, bacilli and *Arthrobacter* species.

Fungal microflora was represented by cellulolytic performant species from genera *Trichoderma* and *Fusarium*.

The quantum structured water stimulated the development of antagonistic microflora and indicated its beneficial role in biocontrol of plant pathogens.

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