Artículo de investigación

Germination of the seeds of lettuce using the aquaponic method

Проращивание Семян Салата Латука при Использовании Аквапонного Метода

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Abstract

The present article shows the data about the germination of the seeds of lettuce wetted with various kinds of water, namely, tap water, water from the river, water from fish tanks, and that from a well. The germination rate of the seeds wetted with the tap water was 94 %, with the water from the river — 97 %, and with the water from the well — 99 %. The highest germination rate was observed in the sample wetted with the water from a fish tank; it reached 100 %. At the end of the experiment the sprouts in the test samples 2.2 times exceeded the reference, by 69.0 and 63.7 %, respectively, which is evidence that germination of the seeds wetted with the water from a fish tank, from the river, and from the well accelerates germination of lettuce seeds. At the end of germination, the average number of leaves in the third and the fourth groups exceeded the reference value by 13.6 %; and in the second group, the number of leaves was greater by 11.4 % than in the reference group. This is evidence that the shoots wetted with the water from the river and a fish tank developed most intensively.

Key Words: Aquaponics, lettuce, seed germination, sampling.

Аннотация

В данной статье приводятся данные по проращиванию семян салата латука при смачивании различной водой, а именно: водопроводной водой, водой из реки, из рыбоводных бассейнов и из скважины. Процент всхожести семян, увлажняемых водопроводной водой, был равен 94 %, водой из реки – 97 %, водой из скважины – 99 %. Наибольший процент всхожести был отмечен в пробе, смачиваемой водой из рыбоводного бассейна, и достиг 100 % всхожести. По завершению опыта ростки опытных проб превышали контроль в 2,2 раза, на 69,0 и 63,7 % соответственно, что свидетельствует о том, что проращивание семян на воде из бассейна, где содержалась рыба, а также на воде из реки и скважины ускоряет прорастание семян салата латука. В конце проращивания в третьей и четвертой группе среднее число листков превысило контрольное значение на 13,6 %, во второй группе число листков на 11,4 % превысило контроль. Это свидетельствует о том, что наиболее интенсивно развивались ростки при увлажнении водой из реки и рыбоводного бассейна.

Ключевые слова: аквапоника, салат латук, проращивание семян, отбор проб.

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Introduction

The conditions of agriculture intensification raise the issue of combining industrial branches; in this regard, aquaponics is becoming more relevant, since it allows obtaining safe products of fish farming and crop production (Krymov et al., 2018a; 2018b; Al-Kodmany, 2018).

Joint fish farming and plant cultivation is a promising area for obtaining food products, which is of great interest both for peasant farms and for larger enterprises. Increased economic efficiency, in this case, is because fish and cultivated plants have similar needs in energy and heat (Grigoriev et al., 2015; Kovrigin et al., 2015; Kuryleva, Yurina, 2016).

In the industrial conditions with the use of intensive technologies (thick planting, feeding), accumulation of fish waste products occurs in the pools with closed or circulating water supply. Their oxidation, as well as oxidation of the feed residues may result in an increased concentration of compounds such as nitrates and phosphates. To avoid the negative consequences of exposure to increased concentrations of these substances, various clarifiers and filters are used; planting density, feeding norms, etc. are monitored.

However, products of nitrogen metabolism (ammonium, nitrites, nitrates) may be used as nutrients for growing various agricultural plants: tomatoes, cucumbers, basil, lettuce, and other crops (GOST 12038-84 Agricultural seeds, 2004; Boxman et al., 2018; Makartsev, 2019; Mustafa, Shapawi, 2015).

Aquaponic technology greatly facilitates the process of plants cultivation. This is due to the possibility to automate all stages of plant care: mineral nutrition, temperature and light conditions.

The advantage of aquaponics is that there is no need of using fertilizers for the plants and that the water saturated with the wastes of fish living activities undergoes an additional natural stage of biological treatment and saturation with oxygen by the plants. The obtained plants have high growth rates and reach the phase of flowering and fruiting sooner. The products obtained from these plants are more biologically valuable since they contain high concentrations of vitamins, sugars, and organic acids. The man can regulate the nitrate content in the obtained product by reducing it to the minimum. Plants that are grown aquaponically feature higher yields than those grown in the soil (Al-Kodmany, 2018; Suhl, 2016; Schmautz et al, 2017).

The first known in the history of the mankind successful experiment in growing plants without soil were the legendary Hanging Gardens in ancient Babylon, one of the seven wonders of the world built by the Babylonian King Nabuchodonosor in the II century BC (605 – 562). It was a unique structure of materials layered on each other and an extensive water supply network for the plants in the garden. Another example of using a nutrient solution for growing plants was the floating gardens of the Aztecs in Central America (Kovrigin et al., 2015; Great Soviet Encyclopedia (GSE), 1969 – 1978). The Nomadic tribes of Indians that had been displaced from fertile lands by their belligerent neighbors used an innovative method of cultivating plants on the banks of the Mexican lake Tenochtitlan. Rafts were made of long cane stalks, and the silt from the bottom of the lake was placed on them. These rafts were called Chinampas. This way, Indians obtained high yield that allowed the tribe to know neither hunger nor need. In the floating gardens, not only vegetables but also fruit trees grew well.

The birth year of the modern crop breeding without natural soil is considered to be the year 1860. It was in this year that Wilhelm Knop (1817 – 1901), Professor of Agricultural Chemistry and the Head of the Leipzig-Möckern Agricultural Experimental Station, together with Professor of Botany at the University of Bonn Julius Sacks (1832 – 1897) first prepared solutions of salts that could be used for growing green plants without soil. For a long time, "vegetation pots" filled with nutrient solutions remained an inherent part of research laboratories.

The first large-scale use of crops grown on water for food production is ascribed by the history to American phytophysiologist Professor William F. Gericke, Associate Professor of the University of California. He first reported his experiments in 1929. The success of his work was confirmed in practice during the Second World War. American troops, while on the barren rocky islands, grew vegetables in hydroponic pools created in the bare rock with the use of explosives. William Gericke also introduced the term "hydroponics". In parallel with American scientists, many European experts were working on the problem of cultivating plants without soil (Grigoriev et al., 2015).

The largest hydroponic installation was created at the Soviet Institute of Fruit-Growing under the direction of Professor D. N. Pryanishnikov. The experiments found practical use as soon as in 1937. During one of the polar expeditions, vegetables for food were obtained this way. Hungarian and Polish scientists were not lagging behind their Russian and American colleagues.
In 1932 – 1933 they created installations in the Carpathian Mountains and to the South of the Lvov city. Polish installations were under the command of Professor V. Piotrovsky, and Hungarian ones — under the command of Professor Paul Roeschler. Both companies were located in mountainous areas and cultivated early vegetables and ornamental plants. In 1938, in the small town of Steinheim, Westphalia (Germany), Professor Hernig created a hydroponic installation that is successfully operating even today. Today, hydroponics is one of the successful areas in crop production. Large installations for the production of vegetables are used in the United States, Japan, Germany, Switzerland, Denmark, Norway, Russia, and other countries worldwide (Great Soviet Encyclopedia (GSE), 1969 – 1978).

Plants get carbon and oxygen from the air and other elements – from the soil, and in the case of hydroponics — from the nutrient solution. Nutrient elements are nitrogen, phosphorus, potassium, calcium, iron, and many others, including microelements. They are required by the plants, and cannot be replaced by anything else. Nutrients are compounds containing these elements.

It is known that in the soil, nutrients are contained in four forms:

1. Firmly fixed in the soil and unavailable for plants;
2. Poorly soluble inorganic salts;
3. Adsorbed on the surface of colloids and available for plants through ion exchange; and
4. Dissolved in the water and available for plants (Kovrigin et al., 2015; Suhl et al., 2015).

Absorption of nutrients from the soil or the nutrient solution is ensured by the root system. The main area of nutrients absorption is the zone of stretching (growth), and the zone of root hairs. It also provides necessary nutrients to the aboveground roots of the plants. It has been calculated that 1 mm2 of the root surface develops 200 to 400 root hairs, which allows the root surface to increase hundreds of times. Root hairs have high absorption capacity. In the meristematic zone, the differentiated vascular system is absent. With that, the phloem is differentiated earlier, and formation of xylem is only observed higher along the root length. It is here that the water with dissolved nutrients moves through.

The basic mass of the ions absorbed by the meristem is used exactly in these cells. A certain amount of ions, especially Ca2+, come from this area to the aboveground organs of the plants. The ions adsorbed in the zone of stretching and the zone of root hairs are transported both up and down the root. Above the zone of root hairs, the zone of root branching is located. Here the surface is covered with a strong cork layer and is virtually not involved in the absorption of nutrients. Various root zones are responsible for the absorption of various mineral elements. It has been found that Ca2+ enters the apical zone, and K+, NH+4, and phosphates are absorbed by the entire surface of the root system (Boxman et al., 2018; Zou et al., 2016).

In aquaponics, the process of nutrients absorption is faster, and the extra oxygen stimulates faster development of the root system. The plant does not have to waste energy searching for nutrients; they are easily available for the roots of the plant. Therefore, the plant uses the saved energy for its development and growth. Also, when plants are grown using aquaponics, less water is used, which is especially important in the cultivation of agricultural products on an industrial scale (Zou et al., 2016).

The research was aimed at studying germination of lettuce seeds on a bed wetted with various kinds of water for subsequent planting in an aquaponic installation.

Materials and Methods

The experiment with germination of lettuce seeds for further planting into an aquaponic installation was performed at LLC Albashi in the Leningrad district of the Krasnodar region in the spring and the summer of 2019. The duration of the experiment was 10 days.

From the seeds of the main crop, four samples of 50 specimens each were taken for determining the germination rate and the germination vigor.

For wetting the substrate of the first sample of seeds, the tap water used, for wetting the second — the water from the regulated flow of the Albashi River in the Leningrad district of the

Krasnodar region, for wetting the third sample — the water used for artificial sturgeon farming (one-year-old bester), and for wetting the fourth sample — the water from the well of the farm. The seeds were pre-rinsed with room temperature water for three minutes, and dried with filtering paper.

The seeds were germinated on beds of two layers of wetted filtering paper in Petri dishes. The bed was wetted every day.

The bed for seeds germination was wetted with a 0.2 % aqueous solution of potassium nitrate. If the bed dried up during the period of germination, it was moistened with water (GOST 12038-84 Agricultural seeds, 2004).

Lighting was provided by natural daylight. On day 10, seeds germination was determined.

The obtained data were processed using the variation statistics method (Lakin, 1990).

Results and Discussion

After germination of four samples of 50 seeds in each, the germination rates were 94, 97, 100, and 99 %, while the average germination rate was 97.5 % (Table 1). For the average germination rate of 97.5 %, the allowed deviation was ± 5 %. Since the actual deviations of the analysis results for individual samples from the mean germination rate do not exceed the allowed value, the analysis needs not to be repeated.

Table 1. Lettuce seeds germination vigor

Indicator	**Sample 1 (tap water)**	**Sample 2 (river water)**	**Sample 3 (the water from the pool)**	**Sample 4 (the water from the well)**
Day 3 sprouts, mm	4.79 ± 0.34	6.93 ± 0.44***	7.86 ± 0.56***	6.18 ± 0.46**
Day 6 sprouts, mm	10.32 ± 1.21	18.57 ± 1.4***	15.71 ± 1.08***	13.21 ± 0.93*
Day 6 leaves, pcs	0.68 ± 0.09	0.96 ± 0.04**	1.07 ± 0.05***	0.61 ± 0.09
Day 10 sprouts, mm	19.68 ± 2.15	44.38 ± 1.76***	33.26 ± 1.56***	32.93 ± 2.3***
Day 10 leaves, pcs	1.76 ± 0.09	1.96 ± 0.04*	2 ± 0**	2 ± 0**

*Note: * – P < 0.05, ** – P < 0.01, * * * P < 0.001*

The presented data show that the length of the sprouts of lettuce on the 3rd day of seeds germination was significantly greater in all experimental groups than in the reference group — by 44.6, 64.1, and 29.0 %, respectively. On days 6 and 10 of the experiment, the length of the sprouts in the experimental groups was also significantly greater than the reference value. On day 10 of the experiment, the sprouts in the test samples 2.2 times exceeded the reference, by 69.0 and 63.7 %, respectively, which is evidence that germination of the seeds wetted with the water from a fish tank, from the river, and from the well accelerates lettuce seed germination.

On day 6, the greatest number of leaves on lettuce sprouts was observed in the third group, and the average value was 1.07 ± 0.05 (P < 0.001), which significantly exceeded the reference value. In the second group, the number of leaves was significantly greater in the reference group — 0.96 ± 0.04 (P < 0.01).

On day 10, the average number of leaves in the third and the fourth groups was 2 ± 0 (P < 0.01), which was greater than the reference value by 13.6 %; in the second group, the number of leaves was 1.96 ± 0.04 (P < 0.05), which was greater than the reference value by 11.4 %.

The presented data show that when the germination bed was wetted with the water from a fish tank, from the river and the well, the emergence of leaves was more intensive.

Discussion

D. A. Sat et al. studied the effect of biostimulants of various origins on the quality of cress sprouts. Seeds germination with the use of various growth stimulants was studied. Its average value was 91.6 %. In the studies performed, the authors use various kinds of water for wetting the bed, rather than growth stimulants. The average seed germination rate was 97.5 %.

The length of the sprouts at the end of germination was studied. In the experiment performed by D. A. Sat et al., the maximum value was 4.0 cm, and in the study of the authors, it was 4.4 cm. This is evidence that with the use of the water from a fish tank for seed germination, it is possible to avoid using growth stimulants.

The germination rate of the seeds wetted with the tap water was 94 %, with the water from the river — 97 %, and with the water from the well — 99 %. The highest germination rate was observed in the sample wetted with the water from a fish tank; it reached 100 %. Since in the sample wetted with the water from the fish pool, the seed germination rate was the highest, it is evidence that the water where fish was grown has a beneficial effect on seed germination.

At the end of the experiment the sprouts in the test samples 2.2 times exceeded the reference, by 69.0 and 63.7 %, respectively, which is evidence that germination of the seeds wetted with the water from a fish tank and the water from the river and the well accelerates lettuce seed germination.

At the end of germination, the average number of leaves in the third and the fourth groups was 2 ± 0 ($P < 0.01$), which was greater than the reference value by 13.6 %; in the second group, the number of leaves was 1.96 ± 0.04 ($P < 0.05$), which was greater than the reference value by 11.4 %.

Conclusion

The results of the experiment make it possible to draw a conclusion that lettuce sprouts developed most intensively when the seeds had been wetted with the water from the river and from a fish tank; therefore, these types of water feature high saprobity, and can be used as a nutrient solution for cultivating aquaponic plants.

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References

Al-Kodmany, K. (2018). The vertical farm: a review of developments and implications for the vertical city. Buildings, 8(2), 24.

Boxman, S.E., Nystrom, M., Ergas, S.J., Main, K.L., Trotz, M.A. (2018). Evaluation of water treatment capacity, nutrient cycling, and biomass production in a marine aquaponic system. *Ecological Engineering*, 120, -310.

GOST 12038-84 Agricultural seeds. (2004). Methods for determination of germination (with Amendments No. 1, 2, corrected). Official edition. Agricultural seeds. Methods of analysis: Collection of GOST standards. PPC Publishing House of Standards, Moscow.

Great Soviet Encyclopedia (GSE). (1969 – 1978). Moscow: Soviet Encyclopedia.

Grigoriev, V.A., Kovalyova, A.V., Sorokina, M.N. (2015). Opyt sovmestnogo vyrashchivaniya klarievogo soma (Clarias gariepinus burchell, 1822) i salata (Lactuca sativa l.) metodom akvaponiki [The experiment of growing sharptooth catfish (Clarias gariepinus burchell, 1822) and lettuce (Lactuca sativa l.) using the aquaponic method]. Natural Sciences, 4(53), 96-101.

Kovrigin, A.V., Kulachenko, V.P., Isaev, P.A. (2015). Razrabotka elementov innovatsionnoi avtomatizirovannoi akvaponnoi tekhnologii proizvodstva selskokhozyaistvennoi produktsii [Development of an innovative automated aquaponic technology of agricultural production]. Belgorodsky Agromir, 3, 8–10.

Krymov, V., Yurin, D.A., Kononenko, S.I., Maxim, E.A., Yurina, N.A. (2018a). Changes of Weight Indicators in Sturgeon Fish When Using Combined Feeds with Various Protein and Fat Contents in Closed Water Supply Installations. *International Journal of Pharmaceutical Research*, 10(4), 316–322.

Krymov, V.G., Galicheva, M.S., Semenenko, M.P., Yurin, D.A., Shumeiko, D.V., Yurina, N.A. (2018b). Possibilities of Implementation of Polyculture for Optimization of Industrial Sturgeon Aquaculture on the Basis of Closed Water Supply Facilities. *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, 9(6), 540–545.

Kuryleva, N.V., Yurina, A.V. (2016). Gidroponika – kak metod vyrashchivaniya zelenykh kultur [Hydroponics as a method of cultivating green crops]. Molodezh i Nauka, 5, 69.

Lakin, G.F. (1990). Biometriya [Biometrics]. Textbook for Biology specialized HEIs, 4th ed., revised and amended. Vysshaya Shkola, Moscow.

Makartsev, E.B. (2019). Hydroponics in extreme conditions. Language and intercultural communication Proceedings of the XI International scientific-practical conference. Astrakhan, 156–161.

Mustafa, S., Shapawi, R. (2015). Aquaculture ecosystems: adaptability and sustainability. Aquaculture Ecosystems: Adaptability and Sustainability, pp. 1–384.

Schmautz, Z., Graber, A., Jaenicke, S., Goesmann A., Junge, R., Smits, T.H.M. (2017). Microbial diversity in different compartments of an aquaponics system. *Archives of Microbiology*, 199(4), 613–620.

Suhl, J., Dannehl, D., Kloas W., Baganz, D., Jobs, S., Scheibe, G., Schmidt, U. (2016). Advanced aquaponics: evaluation of intensive tomato production in aquaponics vs. Conventional hydroponics. *Agricultural Water Management*, 178, 335–344.

Zou, Y., Hu, Z., Zhang, J., Guimbaud, Ch., Wang, Q., Fang Y. (2016). Effect of seasonal variation on nitrogen transformations in aquaponics of Northern China. *Ecological Engineering*, 94, 30–36.

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