



AN OVERVIEW ON THE IMPORTANCE OF WATER IN HYDROPONIC VERTICAL FARMING A STEM TEACHING CURRICULUM

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Welcome to our comprehensive curriculum on the importance and applications of water in hydroponic vertical farming, with special focus on our favorite plant species – LEAFY GREENS. This STEM curriculum aims to provide you with a solid foundation in hydroponic vertical farming techniques, covering essential topics such as the principal applications of water, nutrient solutions relating to pH, EC and DO measurement, and the utilization of nanobubble enhancement techniques. Through an understanding of the principles and best practices of hydroponic vertical farming, you will gain valuable insights into cultivating crops without soil, optimizing space utilization, and achieving higher yields with additional emphasis on the importance of effective water management, including water conservation and sustainability. We also explore the exciting potential of nanobubbles in improving oxygenation, enhancing nutrient uptake, and contributing to disease control. By embracing these innovative techniques, you will have the opportunity to enhance crop productivity and promote sustainability in hydroponic vertical farming.

I. WATERS KEY ROLE IN HYDROPONIC VERTICAL FARMING

In hydroponic vertical farming, water plays a crucial role as a nutrient carrier, delivering essential elements to the plants in a controlled environment. By understanding the principles of hydroponic vertical farming, any grower can grasp the concept of cultivating crops without soil, optimizing space utilization, and achieving higher yields. In highlighting both the advantages and challenges of hydroponic vertical farming, a grower can emphasize the significance of water and ensure sustainable and efficient agricultural practices through water conservation and promoting environmental sustainability.

A. Definition and principles of hydroponic vertical farming

Hydroponic vertical farming refers to a method of cultivating plants in a vertical arrangement, utilizing nutrient-rich water solutions instead of traditional soil-based methods. This innovative approach maximizes space utilization by stacking plants vertically, allowing for increased crop production in limited areas. The principles of hydroponic vertical farming involve precise control of environmental factors such as light, temperature, humidity, and nutrient delivery, creating an optimal growing environment for plants to thrive.

B. Advantages and challenges of hydroponic vertical farming

Hydroponic vertical farming offers numerous advantages, including higher crop yields compared to traditional farming methods due to the efficient use of space. This method also allows for year-round cultivation, overcoming seasonal limitations and providing a constant supply of fresh produce. However, hydroponic vertical farming poses certain challenges, such as the initial investment cost for setting up the infrastructure and the need for precise monitoring and maintenance of nutrient levels, pH, and environmental conditions to ensure optimal plant growth. Additionally, the reliance on artificial lighting in indoor setups can increase energy consumption and costs.

C. Importance of water in hydroponic systems

Water plays a vital role in hydroponic systems as a primary medium for delivering essential nutrients to plants. In hydroponics, water acts as a nutrient carrier, providing plants with the necessary elements for their growth and development. Additionally, efficient water management is crucial for water conservation and sustainability in hydroponic systems, ensuring minimal waste and environmental impact.

- Water as a nutrient carrier

In hydroponic systems, water acts as a crucial nutrient carrier, facilitating the delivery of essential elements directly to the plant roots. Through a carefully balanced nutrient solution, water carries the necessary minerals, such as nitrogen, phosphorus, and potassium, and micronutrients required for optimal plant growth. This nutrient-rich water solution is constantly circulated or delivered to the plant roots, ensuring that the plants receive a steady supply of nutrients for their development and productivity.

- Water conservation and sustainability

Water conservation and sustainability are paramount considerations in hydroponic systems. By utilizing recirculating systems, hydroponics minimizes water usage compared to traditional soil-based agriculture. Techniques such as nutrient film technique (NFT) or drip irrigation systems allow for precise water delivery, reducing waste and optimizing plant uptake. Additionally, implementing water-saving practices such as capturing and reusing condensation or employing advanced water treatment technologies helps ensure sustainable water management in hydroponic operations.

II. WATER & NUTRIENT SOLUTIONS IN HYDROPONIC SYSTEMS

In hydroponic systems, the management of water, nutrient solutions, pH, and electrical conductivity (EC) is crucial for plant health and growth. Perfectly balanced nutrient solutions provide essential elements for plants to thrive without soil. Monitoring and adjusting pH levels in hydroponic systems ensure optimal nutrient availability and absorption by plants, while maintaining an appropriate EC level helps regulate the strength and concentration of the nutrient solution. Understanding these factors and their interactions is essential for achieving successful hydroponic cultivation.

A. Ensuring optimal water quality

Ensuring optimal water quality is crucial for hydroponic growers seeking to maximize plant growth and yield. By conducting water source testing, growers can obtain valuable insights into the composition and characteristics of their water, enabling them to make informed adjustments to their nutrient dosages, electrical conductivity (EC), pH levels, and dissolved oxygen (DO) levels. This knowledge empowers growers to tailor their nutrient solutions to meet the specific needs of their plants, optimize nutrient uptake, and maintain a favorable growing environment. By proactively managing water quality parameters, hydroponic growers can achieve a precise nutrient dosage profile, enhance plant health and vitality, and improve the overall quality and yield of their crops.

Pre-filtration is equally important as it removes impurities, sediment, and contaminants from the water source, preventing clogging in irrigation systems and safeguarding the health of plants. By implementing regular water testing and pre-filtration practices, hydroponic growers can maintain water quality, optimize nutrient delivery, and minimize the risk of plant stress or disease.

- Standard methods for water pre-filtration

One commonly used method is sediment filtration, which involves passing water through filters or screens to remove larger particles, debris, and suspended solids. This helps prevent clogging in irrigation systems and minimizes the risk of blockages in the nutrient delivery lines. Another technique is carbon filtration, which utilizes activated carbon filters to remove organic impurities, chlorine, and other potentially harmful substances that can affect plant health. Reverse osmosis (RO) filtration is another popular method, particularly for removing minerals, heavy metals, and other dissolved contaminants from the water. This process utilizes a semipermeable membrane to selectively allow water molecules to pass

through while filtering out impurities. Additionally, UV sterilization can be employed to eliminate microorganisms and pathogens present in the water, reducing the risk of plant diseases. By employing these pre-filtration techniques, hydroponic growers can ensure the purity and suitability of the water used in their systems, promoting healthy plant growth and optimal nutrient uptake.

B. Understanding nutrient solutions

Understanding nutrient solutions is fundamental in hydroponic systems as it involves providing plants with the necessary nutrients in a water-based medium. Nutrient solutions are carefully formulated mixtures containing essential macronutrients and micronutrients required for plant growth. By comprehending the composition and role of these nutrients, hydroponic growers can create well-balanced solutions that meet the specific nutritional needs of different crops, promoting healthy development and high yields.

- Essential nutrients for plant growth

Essential nutrients are vital elements required for optimal plant growth and development. These nutrients include macronutrients such as nitrogen, phosphorus, and potassium (NPK), which are needed in larger quantities, and micronutrients like iron, zinc, and manganese, required in smaller amounts. Each nutrient plays a unique role in various plant functions, such as photosynthesis, root development, and flower production. Ensuring a proper balance and availability of these essential nutrients is crucial for maximizing plant health and productivity in hydroponic systems.

- Role of macronutrients and micronutrients

Macronutrients and micronutrients both play crucial roles in supporting plant growth and development. Macronutrients, such as NPK, are involved in essential functions like chlorophyll production, energy transfer, and root development. Micronutrients, including iron, zinc, and copper, are essential for enzyme activity, cell division, and overall plant metabolism. Understanding the specific roles and requirements of macronutrients and micronutrients allows hydroponic growers to tailor nutrient solutions to meet the specific needs of different crops and optimize their growth.

- General guideline for NPK levels in hydroponic leafy greens nutrient solution

The recommended optimal NPK (nitrogen, phosphorus, and potassium) levels in hydroponically grown leafy greens nutrient solution can vary based on the specific type of leafy greens, growth stage, and desired yield. However, a general guideline for NPK levels in hydroponic leafy greens nutrient solution is as follows:

Nitrogen (N): Recommended levels typically range from 100 to 200 parts per million (ppm). Leafy greens have a relatively high nitrogen requirement for foliage growth.

Phosphorus (P): Recommended levels generally range from 50 to 100 ppm. Phosphorus is important for root development and overall plant health.

Potassium (K): Recommended levels typically range from 150 to 250 ppm. Potassium contributes to overall plant vigor, disease resistance, and stress tolerance.

It's important to note that these are general recommendations, and specific nutrient requirements can vary depending on the specific leafy green's variety, growth stage, and environmental conditions. Regular monitoring of nutrient levels and adjustments based on plant response and growth goals are key to maintaining optimal nutrient balance for hydroponically grown leafy greens.

- Fertilizer brands available for hydroponically grown leafy greens

There are several reputable and widely used liquid fertilizer brands available for hydroponically grown leafy greens. Preferences and effectiveness can vary based on individual needs and preferences. However, there are several well-established and reputable fertilizer brands that are widely used and trusted within the hydroponic industry. Some of these brands include General Hydroponics, Botanicare, Advanced Nutrients, and FloraFlex. These brands offer a range of nutrient solutions specifically designed for hydroponic systems, and they have a track record of delivering quality products and supporting successful plant growth. It is recommended to review the nutrient compositions, formulations, and customer reviews of assorted brands to determine the best fit for your specific hydroponic leafy green's cultivation needs. Conducting your own research and experimentation can help determine the brand that aligns with your goals and preferences.

B. pH management in hydroponic systems

A critical aspect of hydroponic systems is pH management, as it directly affects nutrient availability and uptake by plants. Maintaining the appropriate pH level is essential for optimal nutrient absorption and prevents nutrient deficiencies or toxicities. Regular monitoring of pH levels and implementing adjustment techniques, such as using pH buffers or acids/bases, ensures that the nutrient solution remains within the ideal pH range for the specific plants being grown, promoting healthy growth and productivity.

- Importance of pH for nutrient availability

The pH level of a hydroponic system is crucial for nutrient availability to plants. pH directly affects the solubility and chemical reactions of nutrients in the water solution, influencing their accessibility to plant roots. Maintaining the proper pH range ensures that nutrients remain in an optimal form for uptake by plants, preventing nutrient deficiencies or imbalances that can hinder growth and yield.

- pH testing and adjustment techniques

Consistent pH testing is an essential practice in hydroponic systems to monitor and maintain optimal pH levels. Testing kits or meters are commonly used to measure the pH of the nutrient solution. If the pH deviates from the desired range, adjustment techniques such as adding pH buffers or using acid/base products solutions like "pH Up" or "pH Down" can be employed to bring it back to the optimal level. Regular and accurate pH testing, along with proper adjustment techniques, ensures a stable pH environment for efficient nutrient uptake and healthy plant growth in hydroponic systems.

- Optimizing pH levels in hydroponically grown leafy greens

The recommended optimal pH levels in hydroponically grown leafy greens nutrient solution typically range between 5.5 and 6.5. Leafy greens prefer slightly acidic to neutral pH conditions. Maintaining the pH within this range is important as it affects nutrient availability and uptake by the plants. Deviations from the optimal pH range can lead to nutrient deficiencies or toxicities, impacting plant growth and health. Regular monitoring and adjustment of pH levels are necessary to ensure the pH remains within the recommended range for optimal growth and productivity of hydroponically grown leafy greens.

C. Electrical Conductivity (EC) and nutrient strength

Electrical conductivity (EC) is a measure of the nutrient strength or concentration in a hydroponic system. It indicates the solution's ability to conduct an electrical current, which is related to dissolved salts and nutrients. Monitoring and maintaining the appropriate EC level is crucial for providing plants with the right nutrient strength, ensuring optimal growth, and preventing nutrient imbalances or toxicities.

- Understanding EC and its relationship to nutrient concentration

Understanding electrical conductivity (EC) is essential for assessing the nutrient concentration in a hydroponic system. EC measures a solution's ability to conduct electrical current, which is directly proportional to the concentration of dissolved ions, including nutrients. A higher EC value indicates a higher nutrient concentration, while a lower EC value suggests a lower nutrient concentration. By comprehending this relationship, hydroponic growers can monitor and adjust the EC level to provide the appropriate nutrient concentration for optimal plant growth.

- Monitoring and maintaining optimal nutrient strength

Monitoring and maintaining optimal nutrient strength are crucial for ensuring healthy plant growth in hydroponic systems. Regular monitoring of the electrical conductivity (EC) allows growers to assess the nutrient strength and make necessary adjustments to maintain the desired levels. By carefully managing the nutrient strength, growers can provide plants with the ideal balance of nutrients, promoting vigorous growth, and maximizing yields.

- Optimizing Electrical Conductivity (EC) levels in hydroponically grown leafy greens

The recommended optimal Electrical Conductivity (EC) levels in hydroponically grown leafy greens nutrient solution typically range between 1.2 to 2.0 millisiemens per centimeter (mS/cm) or 1,200 to 2,000 microsiemens per centimeter ($\mu\text{S}/\text{cm}$). EC is a measure of the nutrient concentration in the solution. Leafy greens thrive in nutrient solutions with moderate to high EC levels. However, it is important to note that specific EC requirements may vary depending on the type of leafy greens, growth stage, and environmental conditions. Regular monitoring and adjustment of EC levels based on crop requirements and plant response are crucial for optimal growth and productivity.

D. Dissolved oxygen (DO) in water and for plants

DO refers to the amount of oxygen dissolved in water, which directly affects root health and nutrient uptake in plants. By regularly measuring DO levels, farmers can ensure adequate oxygenation for roots, promoting robust growth and preventing issues such as root rot. Additionally, monitoring DO allows farmers to optimize system aeration, adjust nutrient delivery, and make informed decisions to create an ideal growing environment for their crops in hydroponic vertical farming setups.

- Monitoring and maintaining optimal DO

Monitoring dissolved oxygen (DO) levels is a crucial aspect of hydroponic vertical farming for enhancing root health and nutrient uptake, while the emerging technology of nanobubbles offers exciting applications such as improved oxygenation, nutrient absorption, and disease control, elevating the efficiency and sustainability of hydroponic vertical farming practices.

- Recommended optimal dissolved oxygen (DO) levels

The recommended optimal dissolved oxygen (DO) levels in hydroponically grown leafy greens nutrient solution typically range between 6 to 8 milligrams per liter (mg/L) or parts per million (ppm). This range ensures sufficient oxygen availability for the roots, promoting healthy growth and nutrient uptake. However, it's important to note that specific DO requirements may vary depending on the specific type of leafy greens, environmental conditions, and nutrient solution composition. Regular monitoring and adjustment of DO levels based on the specific crop's needs and system conditions are key to maintaining optimal growth and productivity. The maximum threshold for dissolved oxygen (DO) levels in hydroponically grown leafy green nutrient solution is around 10 to 12 milligrams (about the weight of a grain of table salt) per liter (mg/L) or parts per million (ppm). While higher DO levels can still be beneficial, exceeding this threshold may lead to diminishing returns in terms of plant growth and nutrient uptake. Additionally, extremely high DO levels can potentially cause oxygen toxicity in the roots, disrupting their functionality. Monitoring and maintaining DO levels within the recommended range is essential to ensure optimal growth and health of hydroponically grown leafy greens.

III. NANOBUBBLES: APPLICATIONS IN HYDROPONIC VERTICAL FARMING

Nanobubbles have emerged as a fascinating technology with promising applications in hydroponic vertical farming. These tiny gas bubbles, offer unique properties such as extended lifespan and high oxygen transfer efficiency. In hydroponic systems, nanobubbles can enhance oxygenation, promote nutrient uptake, and contribute to disease control, leading to improved plant health and productivity. Exploring the generation and utilization of nanobubbles in hydroponic vertical farming opens doors to innovative techniques for optimizing crop growth and sustainability.

A. Introduction to nanobubbles

Nanobubbles (also known as ultra-fine bubbles) are ultra-small bubbles, typically less than 120 nanometers in diameter, with unique physical properties. Due to their extended lifespan and stability in liquid environments, nanobubbles are gaining attention for various applications, including hydroponic vertical farming. Nanobubbles possess distinct characteristics due to their small size, including increased stability and a higher potential for gas dissolution. These properties make them intriguing for use in hydroponic systems.

- Formation and stability of nanobubbles

The formation of nanobubbles can occur through various mechanisms, including cavitation, electrolysis, sonolysis and gas dissolution. However, the exact process of nanobubble formation and stabilization is still an active area of research. It is important to consider factors like bubble size, concentration, and distribution for optimal effectiveness. Factors such as surface tension, interfacial properties, and solution composition influence the stability of nanobubbles, with surface-active substances playing a role in preventing their coalescence and maintaining their presence in liquid environments. Understanding the formation and stability of nanobubbles is crucial for harnessing their potential applications in hydroponic vertical farming and other fields.

B. Nanobubbles in hydroponic systems

Nanobubbles have garnered attention for their potential applications in hydroponic systems, offering several benefits for plant growth and health. In hydroponic systems, nanobubbles can enhance oxygenation levels in the root zone, promoting improved nutrient uptake and overall plant metabolism. Furthermore, nanobubbles have shown potential in disease control, as their small size allows for effective penetration and disinfection, reducing the risk of pathogens and promoting healthier plants in hydroponic setups. Additionally, integrating nanobubble delivery systems into hydroponic setups can ensure proper dispersion and contact of effective gases (such as O₂ and CO₂) and nutrients with plant root systems.

- Nanobubbles enhance oxygenation and nutrient uptake

The presence of nanobubbles in hydroponic systems contributes to enhanced oxygenation, creating an oxygen-rich environment around the plant roots. This increased oxygen availability promotes better respiration and nutrient uptake by the roots, facilitating improved nutrient absorption and overall plant growth. By maximizing oxygenation and nutrient uptake, the presence of nanobubbles can optimize the efficiency and productivity of hydroponic systems.

- Disease control and plant health benefits

Nanobubbles offer potential benefits in disease control and promoting plant health in hydroponic systems. Their small size enables effective penetration into plant tissues, allowing for targeted delivery of disinfectants or antimicrobial agents to combat pathogens. Additionally, nanobubbles can stimulate the plant's immune response and enhance its resistance to diseases, leading to improved plant health and

reduced risk of infections in hydroponic setups. Harnessing the disease control and plant health benefits of nanobubbles can contribute to sustainable and resilient hydroponic vertical farming practices.

- Practical considerations and best practices for nanobubble generation

When it comes to practical considerations and best practices for nanobubble generation, factors such as water quality, system design, and maintenance play key roles. Ensuring high water quality with low levels of impurities helps to achieve stable nanobubble generation. Proper system design, including suitable equipment and flow rates, contributes to efficient and controlled nanobubble production. Regular maintenance, such as cleaning and calibration, helps to maintain the effectiveness of the nanobubble generation system, ensuring consistent and reliable performance for hydroponic vertical farming applications.

There are several companies and brands that specialize in nanobubble technology for hydroponic applications. Some well-known companies in the field of nanobubble technology include Moleaer, Kairospace Technologies, Gaia, Quetrox, Anzai and NanoGas, among others. It is important to conduct thorough research, and consider factors such as technology reliability, 3rd party reports and validation, customer reviews, and support services when choosing a nanobubble technology brand for hydroponic vertical farming. Consulting with industry experts or fellow hydroponic farmers can also provide valuable insights and recommendations for selecting the most suitable brand for your specific needs.

- Measuring effectiveness of oxygenated nanobubbles by monitoring DO

The effectiveness of oxygenated nanobubbles can be measured by tracking dissolved oxygen (DO) measurements in the hydroponic system. By monitoring the DO levels over time, growers can assess the impact of nanobubbles on oxygenation within the nutrient solution. If the nanobubbles are effectively releasing oxygen into the solution, it should result in an increase in the DO levels and remain stabilized for extended time periods under controlled temperature and pressure conditions. Regular DO measurements can help growers evaluate the efficiency of nanobubble oxygenation and ensure that the desired oxygen levels are being maintained for optimal plant growth and nutrient uptake in the hydroponic system.

Congratulations! You have successfully completed the curriculum on the importance and applications of water in hydroponic vertical farming. This comprehensive journey has equipped you with a deep understanding of the principles, challenges, and advantages of hydroponic farming. You have explored the role of water as a vital nutrient carrier and the significance of water conservation in sustainable agricultural practices. Additionally, you have gained insights into the management of nutrient solutions, pH, electrical conductivity, and dissolved oxygen levels in hydroponic systems by understanding their direct impact on plant health and growth. Finally, you have discovered the exciting potential of nanobubbles and their applications in enhancing oxygenation, nutrient uptake, and disease control in hydroponic vertical farming. Armed with this knowledge, you are well-prepared to embark on your own farming endeavors, contributing to the future of efficient and sustainable agriculture.

Best of luck in your future hydroponic adventures!

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About the Author

Jeremy is an independent research scientist and tech entrepreneur with 15 years of groundbreaking analytical and technical research in applied environmental and material sciences, acoustic and vibrational physics, and life sciences. Jeremy specializes in technical project management, research and development, innovative product design and experimental validation of resonance-based water and plasma technologies. He has extensive experience in electrochemical impedance spectroscopy as a method for environmental analysis. Seasoned staff research scientist and managing member of multiple experimental validation teams, with a primary focus to explore, design and implement experimental validation and data acquisition and analysis methodologies for various technologies. He holds a double certification in Quantum Computing at MIT.

In 2019 he co-founded Kairospace Technologies LLC (“Kairospace”), which focuses on pressing water and energy related environmental issues that are currently lacking practical clean solutions. Kairospace provides technology and innovations in building clean energy infrastructures that involve water processes.

As a semi-retired producer/editor of news, corp, doc, entertainment since 1999. Jeremy enjoys documenting and reflecting the human experience in his work with moving images.

In 2009 Jeremy was certified in subtropical permaculture design, specializing in plant medicinal companion planting, eco-gardening, sustainable-homesteading and applied deep ecology.