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What is hydroponic farming?

Hydroponics farming, also referred to as soilless farming, is a method that uses a combination of water and nutrient solution - the water does not reach the plant's roots through soil, but directly instead.

This allows for a massive number of benefits, especially when compared to traditional farming.

To name a few of these benefits:

- **Hydroponic systems are extremely scalable:** Systems can range from only growing a few plants to growing hundreds in a single container! Additionally, vertical farming allows for incredible space saving capabilities, allowing the grower to fully utilize the available space without constraints.
- **There are various types of hydroponic systems:** From Deep Water Culture (DWC) to Aeroponics, hydroponics has the benefit of the grower fully having control over the workings and components of the system. This means that the system can be decided on based on factors such as budget, available resources, space restrictions, plant species, and more, allowing for each system to be customized based on the grower and their farming goals!
- **Hydroponic systems are more cost-effective:** While the initial cost of these systems is higher than traditional farming systems due to the purchase of the needed components, the maintenance costs in the long run will turn out to be much cheaper. This is because hydroponics does not require as much resources (water, pesticides, fertilizer, etc.) as traditional systems when managed efficiently.

To view a more in-depth explanation of what hydroponic systems are and how they work, feel free to watch this informational video: <https://www.youtube.com/watch?v=V0BrgBF9IQM>

About The System

The involved universities

Both Penn State and Belgium Campus partake in this incredible hydroponics project, where students are given the opportunity to collaborate with international partners for a quarterly period.

This offers the following benefits for students involved in this project:

- Interacting with students from another university (and another culture) provides students with the opportunity to learn about different traditions and allows students to see and understand different perspectives and opinions, which improves creativity, critical thinking and problem-solving skills.
- Working with students from another university and cultures encourages collaboration and teamwork, allowing for better informed decisions to be made.
- Participating in the project offers students a hands-on learning opportunity outside of class. Additionally, various soft skills and hard skills will be learned in the process of discovering more on hydroponics systems.
- Students have access to the opportunity of presenting a prototype of the system to primary school students. This will allow students to come up with new and interactive ways of explaining the system to encourage participation and spark an interest of hydroponics in these students.

Project expectations

This project (ENGR 422 for Penn State, and PRJ 381 for Belgium Campus) includes the design, fabrication, test, and presentation of a working hydroponics prototype. It ultimately aims to teach middle school students the importance of nutritional food, general hydroponics concepts, and the engineering principles of hydroponics in a practical, fun, and hands-on manner!

It emphasizes the transformation of communities through education-based engineering.

This can be further expanded on by considering that the project must be culturally accepted, relevant to the community, and also a long-term solution.

Project teams

The project can be broken up into three subsystems. However, it is also important to note that while there will be three project teams, the subsystems must be able to successfully and seamlessly integrate with each other to form the larger system.

The three teams and their design domains are as follow:

- **Hydro team:** Focuses on water flow and structures such as pipes. They are responsible for the primary physical structure, as well as the monitoring of nutrients and water factors.
- **Electro team:** Focuses on electrical aspects and controls. They are responsible for technical aspects such as power constraints and sources, data handling and processing, and the WiFi/networking of the system.
- **Photon team:** Focuses on lighting and plant health. They are responsible for lighting details, such as type, location, and light mapping, as well as all plant-health related factors.

About The Project

The hardware

We chose to utilize PVC pipes, each capable of hosting five plants, as our preferred setup for the hydroponic system. This configuration was selected with the intention of providing an illustrative and comprehensive display of the system's functionality and benefits.

By incorporating a pump into the design, we effectively managed water circulation, promote oxygenation within the nutrient solution, and facilitate the even distribution of essential nutrients to all plants, thus ensuring optimal growth and vitality throughout the system.

Why spinach?

Spinach presents an excellent choice for hydroponic cultivation due to its adaptability to controlled environments and rapid growth rate. With its shallow root system and high nutrient requirements, spinach thrives in hydroponic setups where nutrient solutions can be precisely regulated.

Additionally, spinach's compact size makes it well-suited for vertical farming and space-efficient hydroponic systems, allowing for high yields in limited spaces. Its nutritional density and versatility in culinary applications further enhance its appeal as a prime candidate for hydroponic cultivation.

The software

In a hydroponic system, the integration of light, pH, and flow sensors plays a crucial role in maintaining optimal growing conditions for plants. Light sensors regulate the intensity and duration of artificial lighting, ensuring that plants receive the appropriate amount of light for photosynthesis.

pH sensors monitor the acidity or alkalinity of the nutrient solution, allowing for precise adjustments to maintain the ideal pH level for nutrient uptake by the plants. Flow sensors, on the other hand, monitor the movement of water and nutrients throughout the system, enabling the adjustment of flow rates to prevent overwatering or underwatering.

Together, these sensors contribute to the efficient management of the hydroponic environment, promoting healthy plant growth and maximizing yield.

Sensor History

Water level

Water level plays an important role in hydroponics as it ensures proper plant growth and nutrient uptake. Thus, the water level in a hydroponics system should be constantly monitored.

The system is designed in such a way so that the user will receive a notification if there is too little water in the system or if there is a water leak.

Water level should also be monitored for the following reasons:

- Water level directly affects the availability of essential nutrients to plants, impacting their overall health and development.
- Monitoring water level helps prevent issues such as overwatering or starvation, which can lead to nutrient deficiencies or root rot.
- Effective water level management also contributes to water conservation and sustainable hydroponic cultivation practices.

Flow level

Just like water level monitoring, flow level monitoring is essential in a hydroponics system to ensure the proper circulation and distribution of nutrient solutions to plants. By monitoring the flow level, the teachers can help maintain consistent nutrient delivery, prevent clogs or blockages in the system and optimize water and nutrient usage.

Just as the water level monitoring, the system will notify the user if the flow is either steadily decreasing or if the flow level is at a dangerous level.

The consequences to for not monitoring flow levels are as follows:

- **Uneven nutrient distribution:** Inconsistent flow levels may result in uneven distribution of nutrients to plants, leading to nutrient deficiencies or excesses in certain areas.
- **Clogging or blockages:** Without monitoring, clogs or blockages in the system can occur, hindering nutrient flow and potentially damaging plants.
- **Root suffocation:** Insufficient flow levels can cause roots to become waterlogged or suffocated, leading to root rot and poor plant health.
- **Delayed maintenance:** Insufficient flow levels may be due to system component damage such as pump or pipe damage, not monitoring flow levels may delay component maintenance (this is especially important since South Africa is subject to Load Shedding, that is known to cause damage to electronic devices).

Temperature

Monitoring temperature in hydroponics systems is crucial for maintaining optimal growing conditions and ensuring the health and productivity of plants. Temperature directly impacts plant metabolism, nutrient absorption, and overall growth. Fluctuations in temperature can lead to stress, reduced nutrient uptake, and susceptibility to diseases and pests.

By regularly monitoring temperature levels, growers can make informed adjustments to maintain the ideal temperature range, promote healthy plant development, optimize nutrient absorption, and prevent potential issues such as nutrient deficiencies, root rot, or fungal infections. Consistent temperature monitoring is therefore essential for maximizing crop yields, improving resource efficiency, and ensuring the success of hydroponic cultivation.

- **Stress and Reduced Growth:** Fluctuations in temperature can stress plants, leading to reduced growth rates and overall productivity. Without monitoring, plants may struggle to maintain optimal metabolic processes, impacting their ability to absorb nutrients and develop properly.
- **Nutrient Imbalances:** Temperature fluctuations can affect the solubility and availability of nutrients in the water solution. Without monitoring, nutrient imbalances may occur, leading to deficiencies or toxicities that can harm plant health and compromise crop quality.
- **Increased Risk of Diseases and Pests:** Temperature variations can create favorable conditions for the growth of pathogens and pests. Without proper monitoring and control, the risk of diseases such as root rot or infestations by insects and fungi increases, potentially causing significant damage to crops and reducing yields.

Nutrients

Nutrients play a vital role in hydroponics systems as they serve as the primary source of essential elements for plant growth and development. In a hydroponic setup, nutrients are directly dissolved in water and delivered to plant roots, eliminating the need for soil. This method allows for precise control over nutrient levels and ensures that plants receive the right balance of nutrients they need for optimal growth.

The system will read the nutrient levels and decide when more nutrients should be injected into the system. The system will automatically inject the needed nutrients.

Failure to monitor nutrient levels can have numerous consequences:

- **Nutrient deficiencies:** Without proper monitoring, plants may experience deficiencies in essential nutrients such as nitrogen, phosphorus, potassium, or micronutrients like iron, magnesium, and calcium, leading to stunted growth and poor health.
- **Nutrient imbalances:** Inaccurate nutrient levels can result in imbalances, causing nutrient lockout or toxicity, which can damage plant roots and foliage. (this is especially important in closed systems such hydroponics systems, since the only way to get rid of the nutrients is through plant usage)
- **Reduced yield and quality:** Insufficient or excessive nutrients can impact plant yield and quality, affecting crop productivity and plant health.
- **Pest and disease susceptibility:** Plants with nutrient deficiencies or imbalances are more susceptible to pest infestations and diseases, weakening their overall resilience and health.