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A new Farming Tool: Effective Utilisation of Nutrient Soil Less Culture

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SUMMARY

In regions with significant soil deterioration and scarce water supplies, soilless agriculture represents a viable alternative for such agricultural production industry. This agronomic method also reflects a positive reaction to environmentally friendly farming and a viable instrument in the context of a broader challenge in regards to food security. With an emphasis on the process of plant mineral nutrition, this analysis seeks to identify the drawbacks and potential of hydroponic technologies employed in soilless cropping systems. This review focuses in particular on the mechanisms and processes in hydroponic solutions that guarantee a sufficient nutrient concentration and, consequently, optimal nutritional acquisition without causing nutritional disorders, ultimately influencing crop quality under solubilization or precipitation of micronutrient in the hydroponic solution. Biomass selectivity in the nutrient acquisition process, nutrient competition/antagonism, and interactions between nutrients on emerging technologies that could enhance the planning of soilless cropping systems, such as the use of nanoparticles and helpful microorganisms like plant growth rhizobia on techniques (multi-element sensor systems and interpretation methodologies based on predictive modeling logics to analyse such data). These factors are explored in light of contemporary scientific research that has been used in an industrial setting.

INTRODUCTION

Given that the world's population is expected to exceed 9 billion people within the decade 2050, it is obvious that food production is one of the defining issues of the new century and, thus, the most pressing issue facing the agricultural industry. Nevertheless, it should be remembered that the background is significantly complicated by the gradual loss of rich soil surface caused by environmental degradation and urbanisation processes. In this context, it's also important to consider how the intensification of production times and the agricultural approach encouraged the spread of numerous infections and the emergence of the associated illnesses. The situation is further complicated by the severe reliance of agricultural operations on availability of water in an era of dramatic climatic change (desertification). The soilless systems cultivation is unquestionably a viable option in this regard because it allows for the agricultural exploitation of surfaces that are no longer fertile due to contamination or disease issues) while also lowering water usage. Additionally, it should be noted that this cultivation strategy also serves as a positive reaction to more ecologically friendly agriculture and a viable instrument in the context of the larger challenge of agricultural production. A hydroponic system is completely under the control of the farmer.

To ensure that plants receive the precise nutrition they require, they can control pH and nutrients. Water that isn't utilised by plants is recycled through closed systems. Farmers can regulate temperatures and lighting cycles to increase plant productivity by growing inside. Systems can be created to improve planting density and utilise vertical space. Additionally, we can build farms using hydroponics in areas with unfavourable soil conditions or small spaces that would make it impossible to build a farm otherwise.

Comparing traditional Soil-Grown Crop Production with hydroponics

Water usage that is up to 90percentage points more efficient. Production increases within the same size of space by 3 to 10 times. In a properly managed hydroponic system, many crops could be produced twice as quickly. The nutritive benefits of the finished product rises as harvest and consumption are separated by less time. Farms are allowed to be located in areas with unfavourable weather or soil conditions for conventional food production thanks to indoor agriculture in a climate-controlled environment. When using a hydroponic system, chemical weed and pest management products are not required.

The Greek words hydro, which means "of water," and ponos, which means "labour," are combined to form the English word hydroponics. The science of hydroponics involves growing plants without soil in nutrient-rich solutions, with water carrying nutrients to the roots of the plants. The plants receive continuous nutrient support since their roots are submerged in a nutrient solution.

Currently, 3.5% of the land grown for vegetable production under tunnels and greenhouse uses soilless farming methods based on hydroponic solutions (such as float systems, nutrient film technology (also known as NFT), or aeroponics). This large spread at the field size unquestionably demonstrates the availability of numerous benefits of this production strategy in contrast to the more effective utilisation of water and other nutrient resources. Indeed, there are numerous instances where the use of hydroponic solutions can be effective for biofortification programmes with oligo elements, such as iodine, selenium, silicon, and calcium as well as to enhance the quality and shelf life of vegetables in accordance with consumer and market demands. There is still much potential for development, as evidenced by the comprehensive research activity targeted at fine-tuning fertilizers'/nutrients' content inside the hydroponic solutions, notably to restrict nitrate concentration in edible plant tissues. This is especially true in light of recent scientific findings regarding the mechanisms underlying mineral nutrients in plants as well as their regulation (competition, antagonistic relationships, and interactions among nutrients), as well as the bio-geochemical phases of nutrients in soil solution (solubilization and precipitation). When pursuing the creation of various strategies (including methods and technologies like helpful microorganisms-PGPRs or nanomaterials) for the improvement of the hydroponic vegetable production, this understanding is essential.

Hydroponic gardens are ideal for schools that can't grow plants outside during the winter because they don't need soil and may be kept indoors. Production of food and instruction are made possible indoors, in climate-controlled hydroponic systems, throughout the year, in any weather. Additionally, hydroponics allows for the growth of plants in areas where traditional soil-based farming is impossible due to poor soil quality or a lack of available space.

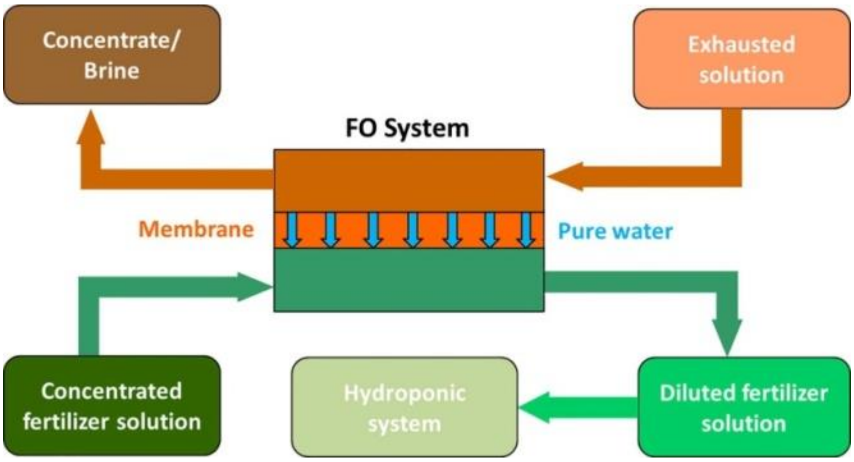
Produce More And Up To Two Times Faster

These hydroponic systems are made to take use of vertical space, which increases planting intensity and food production. Up to 208 plants can be grown in a single fifth-grade educational aeroponics system that has two growing stages and 3' × 4' of available space, which is equivalent to the yield of four 8' x 4' outdoor garden beds. Hydroponic farming also produces up to two times as many plants as soil-based gardening.

A new paradigm known as Industry 4.0, also known as Smart Production, is emerging in the industrial setting. It is built on technologically manufacturing systems and the Internet of Things. It is interesting to highlight that the most significant discrepancies between industrial and agricultural processes will be diminished by the hydroponic cultivation of vegetables conducted out in constrained and well-controlled conditions, which will ultimately improve quality control. But in order to do so, a special set of monitoring tools for the hydroponic-based production strategy is required. In this context, sensors for real-time analysis of the composition of hydroponic solutions (i.e., the availability of nutrients/elements) and interpretation algorithms based on machine learning logics are crucial. In fact, it may only be able to maintain/adapt in real-time the content of a hydroponic liquid in order to produce goods of the appropriate quality owing to these tools, which might be adapted from the industrial environment.

This review aims to analyse the unanswered concerns surrounding hydroponic systems and to highlight prospects for their practical usage on a field scale, while also taking into account current scientific breakthroughs and applications in the workplace. In particular, from a scientific standpoint, we would like to identify the subjects and issues that have received sufficient attention and those that, instead, still call for significant research efforts. All of this data is crucial for improving the supervisors of crop nutrient uptake in soilless systems. Additionally, from a practical standpoint, the possible application of novel nutrients and/or bioeffectors, as well as novel technology for data collection and analysis, could be a useful tool for farmers in the context of smart agriculture at the field scale.

Hydroponic Solutions Used in Soilless Agriculture Techniques



It is well known that the amount of nutrient uptake by plants from the potting medium has a direct impact on the efficiency and crop quality cultivated in hydroponic systems. It is interesting to note that this origin physiological process is influenced not only by the nutrients' availability levels (i.e., by their soluble forms) inside the moderate (solubilization/precipitation: section "Chemical Planning of Nutrient in the Hydroponic Solution"), but also by the nutrients' sources (nutrient chemical types and uptake processes: section "Nutrient Chemical Forms as well as Uptake Processes") and/or by the interactions between the various nutrients.

Chemical Management of Nutrient Availability in the Hydroponic Solution

When dealing with hydroponic cultures, solution chemistry is fundamental to ensure adequate nutrient concentrations for plant uptake. In particular, multiple chemical equilibria must be taken into account when preparing nutrient solutions using salts or concentrated liquid stocks, especially solubilization/precipitation equilibrium. In fact, a number of physical-chemical phenomena can alter the nutrient availability for plants, the most important of which are precipitation, co-precipitation, and complexation. In this respect, it should be highlighted that the temperature of the nutrient solution, affecting the chemical equilibrium in solution, may considerably influence these processes. This is particularly crucial for areas where the over warming of the nutrient solution often occurs, impacting also at the physiological level of crops. When cations and anions in an aqueous combine to produce an insoluble ionic solid, precipitation reactions may take place (the precipitate). Whenever the concentrations of specific anions and cations in solution approach their maximum allowable value, such conditions, known as saturation, occur (solubility).

It is possible to determine the ion concentrations that are in equilibrium with both the precipitation (i.e., solubility) by utilising the solubility product, a specific stability constant that is listed for a variety of chemical compounds and is temperature-dependent. Along with temperature, other factors like pH or ionic strength can also affect the equilibrium of precipitation. Cations must be finely balanced and optimised to prevent losses from solution since they can combine with some other anionic nutrients to generate additional insoluble precipitates or insoluble alkoxides under alkaline pH (by interacting with OH anions). In such circumstances, it is necessary to continuously monitor or regulate the pH and redox potential (Eh) levels.

At pH levels that are acidic, where SiO2 crystalizes may form, silicon solubility is often reduced. Since pH variations frequently encourage precipitation/dissolution processes, pH must be continuously managed or buffered. When nutrients are added to hydroponic solutions in the form of salts, hydrolysis processes may occur that cause the medium to become acidic or alkaline. If nitrogen (N) is solely introduced as NO3 (alkalinization) or NH4 +, the pH of the solution may also change (acidification). However, hydroponic solutions frequently contain both N types. In general, saturation conditions for a particular nutrient could be met if its concentration rises as a result of the hydroponic system's water evaporating.

However, as will be covered later in this analysis, various complexes may have varying effects on how plants absorb and distribute nutrients. Additionally, several types of soluble hydrogen carbonates, phosphates, and chlorides can bind with free metal cations to lower their concentration in solution. Another factor to consider when creating a nutrient solution is the stability of the complexes. While effective complexing agents can make it easier for nutrients to dissolve in water, strong complexes are typically harder for plants to utilise.

Hydroponic farming is especially important in times of crisis. The volume of water that goes into irrigating conventional vegetable farms and fruit orchards is staggering.

CONCLUSION

The application of nanoparticles (NPs) in agriculture is primarily intended to decrease nutrient loses in the environment and to increase yields through the efficient management of fertilizers and water. In fact, nanoparticles may provide the plant with much more soluble and readily available forms of nutrients by limiting the cloud cover and insolubilization processes frequently described for various fertilizers. This is due to their high surface area and relevant reaction (e.g., phosphate ones). Because of this, nanoparticles are regarded as considerably more effective transporters of nutrients to plants than conventional fertilizers. These positive qualities apply to soil systems as well as soilless systems, perhaps even more so (given what is said about chemical equilibrium in hydro solution in the part titled "Chemical Management of Nutrient Supply in the Hydroponic Solution"). As a result, nanoparticles in general and soilless growth systems in particular constitute a viable tool.

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