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Opinion

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Horticulture Protein-Based Systems with Controlled Release of Micronutrients: Microns versus Nanons

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Abstract

Horticulture is seeing an increase in the use of fertilizers. However, the conventional fertilization method is inefficient and causes contamination issues as a result of excessive nutrients. As a result, new technologies like controlled-release fertilizer systems and nanofertilization are currently being tested. As a result, the primary objective of this work was to create controlled-release systems for micronutrients made from soy protein. Zinc, copper, iron, and manganese, as well as their incorporation in the form of micro and nanoparticles, were evaluated. The systems' use in crops, as well as their mechanical and functional properties (water uptake capacity, biodegradability, and micronutrient release), were examined to determine their viability. The findings demonstrated that, when combined with nanotechnology, these systems have a great potential to incorporate micronutrients into crops, enhancing the advantages of conventional fertilization.

Keywords: Micronutrients; Regulated release; Materials made of proteins; Horticulture; Nanoparticles

Introduction

Plants require nutrients, or elements. Even though they are only required in trace amounts, micronutrients play a crucial role in plant growth and development [1]. Horticulture requires seven essential micronutrients: Manganese (Mn), Molybdenum (Mo), Nickel (Ni), Chlorine (Cl), Iron (Fe), Copper (Cu), Boron (B), Zinc (Zn), and For crops to produce high-quality materials of a satisfactory standard, it is crucial to satisfy their requirements for these micronutrients. These micronutrient deficiencies vary depending on the cultivation area, but Zn, Fe, Cu, and Mn are typically the most common. Zn is required for growth hormone production and internode elongation. In addition, it is utilized in the synthesis of chlorophyll and the conversion of starches into sugars (plant energy) as well as in the activation of the enzymes that are responsible for certain proteins. Cu is necessary for numerous enzyme systems and activates specific lignin synthesis enzymes. It is also essential for plant respiration and the photosynthesis process. Fe plays a crucial role because it is necessary for the synthesis of chlorophyll and for other enzymatic and metabolic processes that plants need to complete their life cycle. Lastly, Mn is involved in the synthesis of chlorophyll, vitamins, ATP, lignin, nitrate, hormonal activation, and cell division [2]. As a result, it is critical to compensate for these micronutrient deficiencies without sacrificing production yield. Usually, micronutrients are added to the soil as chelates or sulfate salts to make up for these deficiencies. Sulfate salts are the most common type. However, chelates and sulfates are ineffective because of their high solubility—the amount absorbed by the plant is much lower than the amount that must be incorporated into the soil—especially in irrigated crops. Nanoparticle fertilization, on the other hand, is currently under investigation due to its potential to enhance plant nutrient assimilation. Additionally, the nanoparticles aid plants in mobilizing nutrients for absorption by influencing certain metabolic processes. Lastly, because they are required in small quantities, their application typically incurs lower costs.

The subfield of agriculture known as horticulture is concerned with cultivating plants for human consumption, therapeutic purposes, and aesthetic purposes [3]. The most recent studies indicate that 329.86 million tons of horticulture were produced in total, representing a 2.93 percent increase. Because of the high demand, a huge plantation system was needed, which has the drawback of causing too much soil depletion. Because of this degradation, the soil is unable to efficiently recycle energy and nutrients, so humans must provide both.

Alternatives like conservation tillage or stopping the soil from being contaminated with human waste are among the many research lines that aim to address this issue. Nonetheless, fertilization is the fastest and most common method of avoiding soil depletion. Due to their low assimilation by plants, conventional fertilizers typically result in excess nutrients. Because it takes a significant amount of fertilizer for the soil to improve, this method is ineffective. As a result, an alternative that enhances the conventional method's assimilation efficiency and aids in the introduction of nutrients into plants is essential.

Utilizing controlled-release materials, which make it possible for the nutrients to be delivered gradually, could be an alternative that offers a potential solution to this problem. There are commercial plastics and Multicote from Haifa that are added to the soil to store and release micronutrients in a controlled manner. However, the poor biodegradability of the plastics used in these materials makes it difficult to use them in horticulture. These materials would have clear advantages over bio-based bioplastics in terms of zero toxicity and high biodegradability, making them an appealing option for incorporating vital nutrients necessary for the health and growth of plants in horticulture.

Materials and Procedures

Horticulture is a dynamic field that continues to evolve and adapt to the changing needs of society. As we face the challenges of climate change and population growth, horticulture will play an increasingly

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important role in developing resilient agricultural systems and ensuring a sustainable future. By harnessing scientific knowledge, innovation, and collaboration, horticulture has the potential to make significant contributions to global food production, environmental conservation, and the overall quality of life for individuals and communities around the world.

The controlled release systems were constructed with soy protein isolate (SPI) as a matrix [4]. Protein Technologies International (Belgium) supplied this material, which contains 91 percent protein by weight. In order to create the systems, glycerol, which was provided by Panreac Qumica S.A. (Spain), was used as a plasticizer.

In this study, zinc (Zn), iron (Fe), copper (Cu), and manganese (Mn) were chosen as the micronutrients. They were included in the form of nano- and microparticles. Sulfates of each micronutrient provided by Panreac Qumica S.A. were used in the used microparticles, which are frequently used to make up for deficiencies in horticulture. In contrast, the nanoparticles were chemically colloidal precipitated micronutrient oxides created in the laboratory.

Processing of controlled-release systems

The systems were acquired in accordance with the described procedure. This procedure has five distinct stages: immersion, dehydrothermal treatment, mixing, injection molding, and freezing-dried [5]. First, the raw materials—SPI, glycerol, and micro/nanoparticles—were homogenized in a ThermoHaake, Germany, Polylab QC rotating mixer. The amount of micro or nanoparticles required to achieve the stated percentage was included in the percentage of micronutrients incorporated, which was always fixed at 3.63 weight percent for the purpose of comparing the various systems. Additionally, the ratio of SPI to glycerol remained constant at 1:1. It is important to note that a mixed system (mix) was also carried out, in which a mixture of Zn, Fe, Mn, and Cu supplied the micronutrient percentage. That is, Zn, Fe, Cu, and Mn comprise the percentage of 3.63 weight percent in equal proportions. To produce homogenized blends, the raw materials were mixed for ten minutes at 50 rpm under adiabatic conditions (temperature was always below 35 °C).

The systems' mechanical properties are crucial for confirming their correct operation during transport, storage, and burying in cultivation soil [6]. In order to accomplish this, they were evaluated using dynamic compression. Using a parallel plate tool and a dynamic-mechanical analyzer RSA3, these measurements were taken. From 0.1 to 20 Hz, frequency sweep tests were conducted while maintaining constant temperature and strain (in the linear viscoelastic range). The frequency change was used to evaluate each system's elastic modulus.

Capacity for water uptake one of the advantages of SPI matrices is their high capacity for water uptake, which could act as an additional reservoir of water to lessen the frequency with which irrigation is required. The system was submerged for 24 hours in 300 milliliters of distilled water to evaluate this property.

Analysis of release

These systems' primary goal is to regulate the release of micronutrients [7]. Two distinct protocols were used to determine it. First, the proposed method was used to evaluate it in water. The systems were submerged in 300 milliliters of distilled water to accomplish this. An EC-Metro BASIC 30 device was used to measure the conductivity that the micronutrient release caused in the medium at various times. In contrast, the proposed method was used to evaluate the release in soil as well. Systems were buried in glass tubes in the soil in this manner and irrigated with 20 milliliters of water every 24 hours (similar to intensive horticultural irrigation of 20 liters of water per square meter of soil). Similar to the case before it, the conductivity of the leachates collected from each irrigation was evaluated at various points in time.

Salt release is directly related to conductivity. This way, when it stays the same, it means that all of the salt has been released completely [8]. It is important to note that a reference matrix was also measured and used as a baseline in the various systems. Its conductivity was subtracted in order to only evaluate the release of the salt. Using this method, the maximum conductivity value of 100 percent release was used to calculate and display the salt release percentage over time.

Biodegradability

It is critical that the systems properly biodegrade; To put it another way, they must be broken down after being used without releasing toxic waste. The systems were buried in the soil at 70–80 percent relative humidity and room temperature. So, the soil microorganisms degraded the samples. On various days, the systems were discovered in order to evaluate them visually. Since no pieces larger than 1 mm were found, the estimated biodegradation time was the point at which the systems could not be found.

The ability of these systems to incorporate micronutrients into crops was then evaluated. In this way, crops of Italian sweet pepper (Capsicum annum) and lettuce (Lactuca sativa) were used. To begin, similar specimens were selected for testing after the seeds germinated for three weeks [9]. Commercial farmland, sand, and vermiculite were used in a ratio of 6:2:1 to transplant the germinated plants into 2-liter pots. There were four replicates of each treatment administered to each plant. One matrix was buried at a depth of 2 centimeters beneath the plant's roots for each treatment with the various matrices. In order to compare the effects of the matrices on conventionally fertilized and non-fertilized crops, a positive control and a negative control were also included as references. Every two days, the plants were given enough water to cover them all, and the amount of water needed was recorded. After 40 and 70 days, the various crops were evaluated. They were found for this purpose, and their fresh weight, size, number of leaves, and color were measured. In addition, the inductively coupled plasma-atomic emission spectroscopy method was used to identify the micronutrients absorbed by each plant. An ICP SpectroBlue TI spectrometer was used to analyze the plants after they had been first acid-digested for this purpose.

Statistical analysis

Each measure had at least three replicates (four in plants). Using SPSS, statistical analyses were carried out with a 95% confidence level [10]. Mean values and standard deviations are shown for the results.

Horticulture is a diverse and valuable field that encompasses the cultivation, management, and study of plants. Throughout history, horticulture has played a crucial role in human civilization, providing food, medicine, and aesthetic beauty. As our understanding of plants and their needs has evolved, so too has horticulture, leading to advancements in techniques, technologies, and plant breeding.

One of the primary goals of horticulture is to maximize plant growth and productivity while ensuring environmental sustainability. Horticulturists employ various methods such as soil management, irrigation, pest control, and genetic manipulation to optimize plant health and yield. They also focus on creating aesthetically pleasing landscapes through the design and maintenance of gardens, parks, and green spaces.

In recent years, horticulture has witnessed significant developments driven by scientific research and technological innovations. The use of precision farming techniques, such as hydroponics and vertical farming, has revolutionized plant production by enabling year-round cultivation in controlled environments. Additionally, advancements in breeding techniques have led to the development of improved plant varieties with enhanced traits, such as disease resistance and higher nutritional content [11]. Furthermore, horticulture plays a vital role in addressing global challenges such as food security, environmental conservation, and human well-being. By promoting sustainable practices, horticulturists contribute to the preservation of natural resources, reduction of greenhouse gas emissions, and the creation of green spaces that enhance air quality and promote mental well-being.

Conclusion

In conclusion, horticulture is a multifaceted discipline that encompasses the art, science, and practice of cultivating and managing plants. Its impact on agriculture, environment, and human well-being cannot be understated. As we move forward, horticulture will continue to be at the forefront of sustainable agriculture and environmental stewardship, driving innovation and ensuring a greener and healthier planet.

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Conflict of Interest

None

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