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Editorial

The Tripartite of Soilless Systems, Growing Media, and Plants through an Intensive Crop Production Scheme

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The demands for vegetables, herbs, and fruits have increased, along with the increased human population. Medicinal, aromatic, and ornamental plants have become significant elements in our lives, due to their aesthetics, industrial, and pharmaceutical use and their role in urban greening. Production technology influences plant quality, growth, and yield, enhancing the overall benefits of plants. Soilless culture is a cutting-edge and environmentally friendly way to produce crops. It has become increasingly popular around the world, especially in farming regions where there are water and soil shortages. Soilless culture has become more popular commercially, which has stimulated intense research work.

Soilless cultivation includes all plant growth systems either on porous substrates or on pure nutrient solution (NS) instead of the natural soil. The major advantage of soilless cultivation is the uncoupling of the plant growth from problems associated with the soil, such as soil-borne diseases, non-arable soil, soil salinity, poor physical properties, low temperature, nutrient availability, etc.

The rising interest in growing small/soft fruit crops, vegetables, herbs, and cannabis in soilless container systems has further increased crop production in controlled environment systems worldwide. These systems are used to grow hydroponic and pot ornamentals, seedlings, and transplants, or to increase the content of plant metabolites in medicinal and aromatic plants. Moreover, soilless cultivation has recently gained great interest in urban agriculture and green infrastructure with green roofs, and vertical and rooftop farming.

Effective crop management should be based on a comprehensive strategy that takes plant physiology, growing media, and cultivation methods into account. Nutrient losses, including nitrate and phosphate leaching to water resources, are significantly reduced when excess NS is recycled and controlled, and product quality and safety are maintained. Modern automated nutrient and water supply systems are necessary for modern soilless culture systems to become more sustainable, cost-effective, and profitable. Including organic fertilizers in soilless culture systems is the next step for increasing the sustainability of horticulture.

Due to the increased demand for food production, the out of season vegetables production is necessary under greenhouse conditions. Additionally, farmers need to optimize all elements that affect yield and produce quality in order to meet the high customer demand for high-quality food. This is also necessary in order to recover the expensive investments of greenhouse and/or soilless culture crop production systems. Additionally, soilless systems are better suited for year-round production of high-quality vegetables and cut flowers and have considerably more ability to limit the emissions of nutrients and plant protection products. Furthermore, soilless culture can also be used to produce

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fresh vegetables in desert areas and for urban agricultural production and especially in vertical farming systems. Vertical farming is a unique method in which plants are grown in multiple layers installed into closed constructions that are opaque to sunlight, using LED lamps for artificial lighting and full climate control. Vertical farming can rely on the knowledge and experience of other soilless cultivation systems.

The current Special Issue "The Tripartite of Soilless Systems, Growing Media, and Plants through an Intensive Crop Production Scheme" compiles one critical review and thirteen original research articles, addressing recent developments in growing plants in soilless culture, i.e., hydroponics and growing media, with special attention to horticultural sciences; plant physiology; root media; plant propagation; plant nutrition and chemistry; chemical, physical, and biological substrate properties; compost and waste management; engineering; and all other research fields related to soilless culture and growing media. The present Special Issue contains scientific papers of a high-quality standard coming from several prestigious and renowned research groups.

When using renewable organic materials as a substitute for peat or mineral wool, several issues may occur, such as the possible presence of undesired organic compounds and excess of mineral elements, an uncontrolled bioactivity in the root zone, the preservation of the substrate's original properties throughout the cultivation cycle, and the ongoing availability of these materials on the market. The considerable variability of these materials, which depends on both the feedstock utilized and the production technique, is likely one of the biggest barriers to the adoption of renewable organic growing substrates. Fortunately, the use of standardized production techniques may help to partially solve this issue.

Under nursery and greenhouse conditions, peat-based material is the principal constituent of media extensively used in nurseries for production of young and potting plants. Approximately 14–20% of extracted peat is released to the horticulture sector. Due to the high cost of peat extraction, transportation, and environmental constrains, alternatives to peat are examined. A critical review article was published by Atzori et al. [1], highlighting the role of four organic materials, i.e., biochar, coir, green compost, and wood fibres, in plant nutrition and protection when used as components for the preparation of growing media in the soilless cultivation of containerized crops. Bioactive organic compounds (e.g., humic and fulvic acids) are released from the decomposing organic components and can act as biostimulants enhancing flowering, plant growth, fruit set, crop productivity, nutrient, and water use efficiency. Moreover, Cacini et al. [2] tested green compost, coconut coir dust, and woody fibre, used alone or in mixtures, examining the acidification process (decreasing the pH about 1, 1.5, or 2 units, without increasing the EC to undesirable levels, which might decrease the agronomic value of the matrices) with the addition of the elemental sulphur chips to be considered in developing new substrates. However, during the acidification process, the rapidity of pH acidification and EC increase on plant and mineral nutrition should be further investigated.

For a closed system of soilless growing, the quality of the drainage waters leaking from cultivation mats is a key factor, determining the possibility of their reuse in nutrient solution circulation system. In a study of Dysko et al. [3] the suitability of various substrates (rockwool, coir substrate, a lignite substrate, and a biodegradable organic substrate) for application in a closed system of soilless tomato cultivation was compared, based on the potential fitness of drainage waters from these substrates for recirculation. The lignite substrate revealed several positive properties being a good substitute for rockwool, however, the biodegradable organic substrate may not be a very good alternative to rockwool. Moreover, Nguyen et al. [4] evaluated *Miscanthus* $\times$ *giganteus* biomass for its efficiency as growing media when processed into shreds and chips, in comparison with peat and coir. It was concluded that a primary mechanical modification of miscanthus offers opportunities for different sizes of substrate materials with few changes to the physical or chemical properties of the media tested. Vandecasteele et al. [5] evaluated the differences between compost types in terms of their role in growing media, i.e., composts for bulk use vs. composts used as organic fertilizers, and possibility to replace even 70% v/v the peat-based media.

Woody composts have the potential to be used in high vol% in growing media blends, resulting in a higher degree of nitrification, but the blends still need further optimization when supplemented with organic fertilizers. New materials in growing media (composts and wood, miscanthus, or other plant fibres) are characterized by a higher microbial biomass and activity with potential advantages (e.g., nitrification, acidification based on elemental S, beneficial fungi, and bacteria) and disadvantages (e.g., N immobilization, pathogens).

Another important issue raised in the current Special Issue is the sustainable control of the irrigation in soilless culture. Palumbo et al. [6] concluded that sensor-based irrigation is a feasible approach for the optimal water management of soilless vegetable crops with low environmental impact. In the specific case of green bean, sensors allowed to save water compared to timer-based irrigation management by adapting water supply based on real plant consumption and minimizing leaching.

Soilless culture is the advanced growing technique providing the appropriate nutrient levels to the plants under controlled (usually) conditions, i.e., greenhouse cultivations. Phosphorus is a fundamental macro-element in nucleic acids, high-energy compounds cell membranes, and participates in the process of photosynthesis and respiration, influences gene expression, and activates or causes the inhibition of enzymes by phosphorylation. Sobczak et al. [7] examined the use of polyphosphates for fertigation in pepper hydroponic cultivation and obtained increased photosynthetic activities of the pepper leaves, having positive effect on the marketable yield and calcium uptake, which reflected less cultivar susceptible to blossom end rot (BER). Nitrogen is another important nutrient for plant development and is the sole nutrient that can be delivered to plants in both anionic (nitrate; $NO_3{}^-$) and cationic (ammonium; $NH_4{}^+$) form by fertigation, and both N forms have different absorption rates depending on their external concentrations. Tzortzakis et al. [8] evaluated the ammonium to total nitrogen ratio (Nr) in saline growing tomato plants and revealed salinity enhances fruit quality and improves the organoleptic characteristics of the crop, while an appropriate Nr ratio may restrict the detrimental effects of salinity on the nutritional status of plants by regulating the pH in hydroponic systems.

The awareness of the functional properties of the horticultural product and the new eating habits of consumers have prompted researchers and producers to experiment with new agronomical practices, such as nutrient solution management and use of biostimulants for elicitation of maximal nutritional and nutraceutical quality in vegetables under optimal or under sub-optimal conditions. In fact, a mild to moderate nutritional or salinity stress (eustress) may elicit plant defence responses by inducing the synthesis and accumulation of bioactive compounds, particularly those able to detoxify reactive oxygen species (ROS) and promote plant hardening. Carillo et al. [9], demonstrated that a mild to moderate nutritional stress (eustress) can remodulate plant metabolism by inducing the synthesis and accumulation of beneficial metabolites, improving the plant defence system, productivity, and quality of the final products. However, the choice of the correct eustress type and dose to induce the synthesis of these protective phytochemicals is pivotal to avoid potential interference with plant growth and productivity. Another work on eustress was by Łazny et al. [10] who demonstrated the positive effects of the biodegradable lignite substrate and eustressor in the form of high EC nutrient solution (7.0 $dS \cdot m^{-1}$) on morphological and physiological parameters, as well as the quality and yield of cucumber (*Cucumis sativus* L.) in soilless cultivation compared to the relevant high EC nutrient solution when rockwool was used as substrate.

Biofortification is attracting research interest nowadays, and strawberry plants appeared to be a potential target for selenium (Se) biofortification to increase human intake of this important micronutrient without affecting growth and yield parameters, when Se was used in $\leq$5 mg L^{-1} [11]. Arbuscular mycorrhizal fungi (AMF) are commonly used plant symbionts that affect plant growth, and its effectiveness is plant species-specific. Mycorrhizal inoculation can enhance the nutritional value of strawberry fruits by stimulating the antioxidative mechanisms and nutrient accumulation of the strawberry fruits [11]. Interestingly, mycorrhizae alleviated the induced stress that the high Se levels may cause on the plants.

Mycorrhizas are not the only organism used in agriculture while the beneficial role of bacteria, such as *Bacilllus* spp., is well documented. Kasozi et al. [12] examined the effect of *Bacillus* spp. on lettuce growth and root-associated bacteria community in a small-scale aquaponics system. This study showed that *Bacillus* supplementation can effectively alleviate nutrient deficiencies, improve water quality, and modify the composition of bacterial communities in aquaponics systems, with Bacillus-treated systems, containing significantly higher numbers of *Chryseobacterium*, *Bacillus*, *Nitrospira*, *Polynucleobacter*, and *Thermomonas.* Serious nutritional imbalances in crop production via hydroponics can be obtained via cyanobacteria that are rapidly formed harmful algal blooms (HABs). Gil et al. [13] tested the effects of 11 aqueous extracts of 10 allelopathic plants in controlling *Microcystis aeruginosa* as a solution for ecologically sustainable control of algal blooms, with walnut husk and rose leaf extracts exhibited high inhibitory levels for efficient control of algae. In this study, the high inhibitory effects were related to the high levels of water-soluble tannins, especially tannic acid.

The integration of soilless with other production systems, such as in the case of aquaponic as highlighted in the work of Kasozi et al. [12], is an additional positive aspect of this cultivation system. Another interesting application of hydroponics is in urban farming, as Ezziddine and Liltved [14] suggested that hydroponic rooftop-grown lettuce can be competitive with their indoor counterparts if the rooftop hydroponic system is protected from extreme weather conditions.

Conflicts of Interest: The authors declare no conflict of interest.

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