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Editorial

Greenhouse Management for Better Vegetable Quality, Higher Nutrient Use Efficiency, and Healthier Soil

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1. Introduction

Greenhouse cultivation provides an artificially controlled environment for the off-season production of vegetables, and has played an increasingly important role in agriculture production systems in recent decades. With the exception of soil-less cultivation, vegetables are directly cultured in the soil in most Asian, European, and North American greenhouses. Compared with open-field cultivation, more fertilizer is invested in intensive vegetable production in greenhouses to preserve and increase yields. Thus, after a few years of growth, deteriorated vegetable quality, decreased nutrient use efficiency, and degenerated soil property usually emerge. A well-known reason for these drawbacks is that the vegetables are grown under sub-/supra-optimal greenhouse conditions and suffer diverse abiotic stresses, including extreme temperature, irradiance, poor water condition, a lack of nutrient availability, inappropriate CO_2 concentration and salinity, etc. Recent works have shown that improving greenhouse conditions can promote the growth of vegetables and enhance the uptake of nutrients, leading to better vegetable quality. Meanwhile, greenhouse conditions not only directly influence soil nutrient cycling processes and properties, but also indirectly affect them by regulating vegetable root growth and plant–soil interactions.

This Special Issue (SI), entitled "Greenhouse Management for Better Vegetable Quality, Higher Nutrient Use Efficiency, and Healthier Soil", aims to highlight state-of-the-art greenhouse management that can contribute to increasing vegetable yield and quality, improving nutrient and water use efficiency, and achieving environmentally sustainable utilization of greenhouse soil.

2. Special Issue Overview

This SI features twelve original research articles dealing with the effects of novel greenhouse practices and strategies on the yield and quality of horticulture crops, as well as greenhouse soil properties. Among these publications, three studied the effects of fertilizers, including organic and macro- and micro-nutrient fertilizers, on the growth and nutrient uptake of vegetables [1–3]. Two articles described the effects of water and nutrient supply using irrigation or hydroponic supplying systems on the yield and quality of vegetables [4,5]. Four articles investigated the effects of environmental conditions (mainly light and temperature) on the growth and quality of vegetables [6–9]. In terms of degenerated greenhouse soil, three articles showed how reductive soil disinfestation (RSD) decreased soil salinity, improved soil quality, and inactivated soil-borne pathogens [10–12].

2.1. Fertilizers

Fertilizer is one of the most important factors affecting the yield and quality of greenhouse vegetables, and manure fertilizer coupled with mineral fertilizer is commonly used in greenhouse vegetable cultivation. Sallam et al. [1] compared the effects of various combination ratios of manure and mineral fertilizer on the productivity parameters of greenhouse cucumber. The authors found that the maximum cucumber yield was achieved when 30 kg poultry manure coupled with 3 kg mineral fertilizer was added to coco-peat per cubic meter. The vegetative growth, yield productivity, and fruit quality of cucumber were significantly enhanced when 3 kg mineral fertilizer was applied. Less mineral fertilizer inhibited yield formation, whereas more mineral fertilizer delayed the fruiting stage.

Concerning nitrogen fertilizer, the NH_4^+/NO_3^- ratio has a great impact on vegetable growth and nitrogen utilization. Wang et al. [2] determined the effects of different NH_4^+/NO_3^- ratios in nutrient solution on the growth and nitrogen uptake of Chinese kale. The optimum NH_4^+/NO_3^- ratio was found to be 25/75 to ensure the best growth, the highest fresh and dry weight, and the highest indices of root growth in Chinese kale. Meanwhile, the total N accumulation and N use efficiency were also highest at an NH_4^+/NO_3^- ratio of 25/75. A higher NH_4^+/NO_3^- ratio (50/50) promoted the growth of Chinese kale seedlings at the early growth stage but inhibited it at the late stage, mainly due to the excessive addition of NH_4^+-induced rhizosphere acidification and ammonia toxicity.

In addition to macro-nutrient fertilizers, micro-nutrient fertilizers also play an important role in greenhouse vegetable growth and quality. Xu et al. [3] investigated the effects of four boron levels and two application methods (leaf and root application) on the growth, fruit quality, and flavor of tomato under greenhouse conditions. The results revealed that both application methods significantly increased the net photosynthetic rate and chlorophyll content and stabilized the leaf structure of tomato, mainly due to the improved antioxidant capacity. Leaf spray of 1.9 mg L^{-1} H_3BO_3 was the most effective done for improving the plant growth and photosynthetic indices of tomato, and root application of 3.8 mg L^{-1} H_3BO_3 resulted in better fruit quality and flavor. This work also showed that the application of boron can directly or indirectly regulate the synthesis of volatile substances in tomato fruit.

2.2. Water and Nutrient Supply

Vegetables are highly water-dependent horticultural crops, so water supply could significantly affect the yield and quality of greenhouse vegetables. Ju et al. [4] regulated the greenhouse soil moisture by adding zeolite and alternate drip irrigation, and evaluated the coupling effect of water–zeolite on tomato growth, physiology, yield, quality, and water use efficiency. Using the principal component analysis method, the optimum water for tomato planting was 100% water surface evaporation and the addition of 6 t ha^{-1} zeolite, under alternate drip irrigation conditions with mulch.

The ratio of water and nutrients determines the strength of the nutrient supply, which is also a key factor in the yield forming and quality optimization of horticultural crops. Mouroutoglou et al. [5] compared the effects of four soil-less culture systems (i.e., aeroponic, floating, nutrient film technique, and aggregate systems) on growth, yield, and nutrient uptake in the Greek sweet onion landrace. The results showed that the highest plant biomass, onion yield, and water use efficiency were obtained in floating and aggregate systems, mainly due to the sufficient water and nutrient supply and decreased limit on root growth, when compared with the nutrient film technique. The highest tissue macronutrient concentrations were found in aeroponic and nutrient film technique systems, probably due to root prevalence and condensation effects, respectively. Moreover, the macronutrient uptake concentrations in this study provided a sound basis for the establishment of nutrient solution recommendations for sweet onion cultivation in different closed soil-less culture systems.

2.3. Environmental Conditions

One of the topics addressed in this SI is how to manipulate environmental conditions in a greenhouse to improve vegetable growth and quality. Light is one of the most important environmental factors controlling plant growth and development, so it is essential to determine the light intensity and photoperiod in greenhouse vegetable production. Cui et al. [6] investigated the effect of daily light integral, including the light intensity and photoperiod, on cucumber plug seedlings in an artificial-light plant factory. The optimal daily light integral was 6.35 mol m^{-2} d^{-1}, the optimal intensity was 110–125 μmol m^{-2} s^{-1}, and the optimal photoperiod was 14–16 h to achieve higher plant biomass, shoot dry matter rate, seedling index, and photochemical efficiency. Jiang et al. [7] studied different supplemental lighting modes on the fruit quality of cherry tomatoes in greenhouse production. The results showed that the appearance, flavor quality, nutrient indicators, and aroma of cherry tomato fruits under continuous supplemental lighting and dynamic altered supplemental lighting were generally higher. Considering the electrical cost, dynamic altered supplemental lighting was suggested as a cost-effective supplemental lighting mode for high-value greenhouse cherry tomato production.

The cover materials of greenhouses, such as films or screens, also have a great impact on the microclimate conditions in the greenhouse, and the consequent effects on the vegetable growth and quality are worth exploring. Yamaura et al. [8] examined the physiological and morphological changes in tomato growth and fruit quality in a high tunnel covered with near-infrared reflective film. They found a decrease in total dry matter, resulting from a lower transmitted photosynthetic photon flux density and leaf area index; moreover, they found lower photosynthetic capacity in single leaves because of a decrease in both total nitrogen and chlorophyll content under the near-infrared reflective film. However, the fruit cracking rate was significantly decreased under near-infrared reflective film due to the lower fruit temperature and decrease in fruit dry matter. Therefore, marketable tomato yields can still be guaranteed under near-infrared reflective film. Wen et al. [9] studied the effects of insect-proof screens on the microclimate, reference evapotranspiration, and growth of Chinese flowering cabbages. The results showed that insect-proof screens significantly decreased wind speed and slightly decreased total solar radiation; however, they increased the daily average air humidity, as well as air and soil temperature in the screenhouse. The microclimate improvement resulting from insect-proof screens caused the yield of Chinese flowering cabbages and the irrigation water use efficiency to significantly increase.

2.4. Restoration of Degenerated Soil

Keeping sustainable utilization in mind, the restoration of degenerated greenhouse soil due to RSD practice was investigated. Liu et al. [10] found that the electrical conductivity and available nutrient (NO_3^--N, NH_4^+-N, available K, and available P) content, the abundance of fungi, potential fungal soil-borne pathogens (*F. oxysporum* and *F. solani*), and fungi/bacteria were significantly increased in the plastic-shed soil compared with those in the nearby open-air soil. Meanwhile, the organic fertilizer treatment could not effectively improve the plastic shed soil properties, in which the electrical conductivity and the abundance of potential fungal soil-borne pathogens were even higher. In contrast, soil EC, NO_3^--N content, the abundance of the fungi *F. oxysporum* and *F. solani*, and the ratio of fungi to bacteria were remarkably decreased in the RSD-treated soil, while soil pH, the abundance of bacteria, total microbial activity, metabolic activity, and carbon source utilization were significantly increased. Further study revealed that the RSD treatment effectively enhanced microbial interactions and functions, and the microbial network was more complex and connected [11]. Specifically, hydrocarbon, nitrogen, and sulfur cycling functions were significantly increased in RSD-treated soil, whereas bacterial and fungal plant pathogen functions were decreased. On the other hand, Zhu et al. [12] studied how to improve the efficiency of RSD by optimizing the soil water content and organic amendment rate. The results showed that increasing the soil water content and maize straw application rate elevated the soil pH and accelerated the removal of excess sulfate and nitrate in greenhouse soil; moreover, it considerably increased the levels of organic acids that could strongly inhibit soil-borne pathogens. They found that holding 100% WHC and applying maize straw to 10 g kg^{-1} soil created the optimum conditions for RSD field operations for the effective restoration of degraded greenhouse soil.

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