horticulturae

Editorial

Managing the Product Quality of Vegetable Crops under Abiotic Stress

Lilian Schmidt [1,2]

[1] Professorship for Vegetable Crops, Hochschule Geisenheim University, Von-Lade-Strasse 1, 65366 Geisenheim, Germany; Lilian.Schmidt@hs-gm.de
[2] Professorship for Soil Science and Plant Nutrition, Hochschule Geisenheim University, Von-Lade-Strasse 1, 65366 Geisenheim, Germany

1. Introduction

Plants, as sessile organisms, are continuously exposed to varying environmental conditions and often face abiotic and biotic threats. Biotic stressors include pathogens such as fungi, bacteria or herbivores that can damage plant tissues locally and systemically. In addition to this, abiotic stress, such as sub- and supra-optimal temperatures, the availability of water, light conditions and nutrient supplies, may severely impact the performance of plants. This includes the effects on photosynthetic processes, growth and developmental alterations and modifications in metabolic pathways.

In consequence, plants have developed a wide range of strategies to cope with the challenging conditions, mainly the alteration of growth processes and the investment in defensive compounds [1]. These two strategies often represent a dilemma for plants as they require different resource allocation patterns.

When cultivating plants for use in human nutrition, farmers are faced with a similar dilemma: Besides a high crop yield, there is an increasing demand for products that are rich in health-promoting substances. These beneficial compounds are mostly secondary plant metabolites that are synthesized as a consequence of abiotic or biotic stresses. This is especially true for vegetable crops that are rich in secondary compounds such as polyphenols or carotenoids. In addition, vegetables can contain substances with undesired properties, e.g., oxalates and nitrate. It is thus of interest to cultivate vegetable crops with maximum contents of beneficial compounds and minimal contents of unfavorable compounds, as well as high yields.

Significant research is focusing on pre- and post-harvest procedures that can be used to achieve these goals. Abiotic stress is often applied by employing certain cultivation practices and storage conditions in order to maintain and potentially improve the internal and external properties of vegetable crops.

2. Special Issue Overview

This Special Issue compiles 11 manuscripts that deal with the effects of abiotic stress on the modulation of vegetable quality. It comprises 10 research articles and 1 review. The majority of the contributions deal with pre-harvest conditions and investigate whether cultivation practices can modulate the yield and nutritional value of vegetable crops and herbs under abiotic stresses. Among these publications, several deal with nutrient supply [2–5], salinity [6,7], water supply [2,3,8] or lighting conditions [6]. Two manuscripts describe either the effects of applying chemical substances such as gibberellic acid [9] or seaweed extract [10] on the yield and quality of vegetable crops. Grafting as a method to mitigate the impacts of abiotic stress in vegetables was elucidated by a research paper by Ellenberger et al. [3] and in a review by Devi et al. [11]. Elevated CO_2 levels were either used as pre-harvest conditions in combination with different nitrogen forms [5] or as post-harvest treatment combined with different methods of packaging [12].

check for updates

Citation: Schmidt, L. Managing the Product Quality of Vegetable Crops under Abiotic Stress. *Horticulturae* **2022**, *8*, 25. https://doi.org/10.3390/horticulturae8010025

Received: 1 December 2021
Accepted: 14 December 2021
Published: 26 December 2021

In general, a large quantity of the contributions in this Special Issue present data on fruit vegetables such as watermelons, bitter gourd and tomatoes [2–4,9,11], with the latter being the focus of three publications. These crops were mostly grown in greenhouses [2–4], but some were grown in an open field [9] or under rain-out shelters [8]. Leafy vegetables and herbs—such as arugula [5], purslane [6] and basil [7]—were used in three experiments and were cultivated in growth cabinets [5,6] or in greenhouses [7]. The bulbs of onions were harvested from plants in a field trial [10], and the asparagus spears for a storage experiment were obtained from local farmers [12].

Altogether, a wide range of species, cultivation conditions and management practices (pre- and post-harvest) were used for elucidating the effect of abiotic stress on the quality of vegetable crops.

2.1. Impacts of Reduced Water Supply

The availability of water for the irrigation of vegetable crops will become of high relevance in the future; while heavy rainfall is predicted to occur more frequently, the opposite will be the case as well, with more and longer drought events as compared to the present conditions. One way to overcome these challenges is the use of vegetable varieties that are able to cope with these extreme conditions. Besides the breeding activities that aim at creating more resistant varieties, the use of traditional varieties that may be better adapted to specific situations is being increasingly suggested. In their study, Sica et al. [8] tested the local bean accessions of Veneto, Italy, concerning the yield potential and nutritional properties of the seeds as consequences of drought exposure during different growth stages. Interestingly, exposure to drought had no impact on the yield of dry seeds until the flowering phase. In general, most impacts on the nutraceutical properties of the bean seeds could be explained by variety, and rather little can be assigned to the drought treatments. One bean accession turned out to be most promising for cultivation in areas with increased risk of drought events.

2.2. Effects of Alterations in Nutrient Supply in Combination with Other Abiotic Stresses

Mineral nutrients are essential for plants. When applied in concentrations or forms that are not optimal for the crops, this may have consequences for the performance of plants and their products. Three contributions to this Special Issue deal with yield and quality aspects of tomatoes under different nutritional conditions that are regarded as "stressful" for the plants. Specifically, Ellenberger et al. [3] addressed the question of how grafting two commercial tomato varieties may affect the yield and fruit quality when exposed to a combination of nutrient deficiency and drought stress. They used the commercial rootstock 'Beaufort', two novel hybrid rootstocks of *S. pennellii* × *S. lycopersicum*, which are expected to be drought tolerant, and self-grafted plants. When exposed to a 50% reduction in fertigation, the 'Lyterno' variety grafted onto the novel rootstocks had higher fruit yields as compared to the plants grafted either on the commercial cultivar or the self-grafted plants. This was not observed for the tomato cultivar 'Tastery', which, in general, showed weak responses to the imposed stress. For all the combinations of grafting and fertigation supply, little effects in terms of fruit quality were assessed. The use of appropriate scion–rootstock combinations may thus provide potential for optimizing the stress resilience, the yield and the quality of tomatoes.

Moreover, de Luca et al. [2] combined potassium (K) supply and water shortage treatments for tomatoes, using a commercial cultivar and a transgenic line that may accumulate large quantities of K. The study aimed at testing whether different K supplies can alleviate the impact of periods of dehydration. Although it was obvious that the larger supply of K was able to increase the shoot growth and fruit yield under water stress, this did not result in yields comparable to those obtained for well-watered plants. Moreover, the transgenic tomato line with increased capacities to accumulate K turned out not to be beneficial under water stress in terms of fruit yield.

In another study on tomatoes, Schmidt and Zinkernagel [4] investigated the effects of fertilization with 50% less nitrogen (N) than recommended on the quality of three different varieties of cocktail tomatoes immediately after harvest and after eight days of storage at low temperatures. It was shown that the reduction in N had little effects on the yield, external quality and on the concentrations of valuable compounds in the tomato fruits. In addition, there were no impacts on the taste, as observed by a trained sensory panel, suggesting that the reduced N supply was not detrimental for the three varieties of tomato, at least under the experimental conditions.

One manuscript describes the effects of elevated atmospheric CO_2 levels and N forms on the physiological processes, crop yield and nutritional quality of the leafy vegetable arugula [5]. Plants of two arugula varieties were grown in climate cabinets with either 400 or 800 ppm CO_2 and received either pure nitrate or ammonium-dominated nitrogen fertilizer. Replacing 75% of nitrate-N with ammonium-N had little impact on photosynthetic CO_2 assimilation, the nutritional quality (e.g., content of anti-oxidative compounds) or was disadvantageous for crop yield, regardless of the CO_2 levels. Thus, ammonium-dominated N provides no benefits for arugula production under the elevated CO_2 levels that are proposed for the future.

2.3. Impact of Salinity

Salinity is characterized by increased electrical conductivity due to an accumulation of mineral elements. Specifically, the enrichment with sodium (Na) and chloride (Cl) ions in the soil imposes a worldwide threat to plant production. However, as a mild stressor, saline conditions can be used to alter the quality of horticultural products.

This was conducted by Corrado et al. [7] by supplying sweet basil plants in hydroponics with three nutrient solutions with differing NaCl concentrations. Even low concentrations of NaCl (20 mM) resulted in reduced biomass development, while having positive effects on some nutritional quality parameters, such as antioxidant capacity and total polyphenols.

In a study by Giménez et al. [6], much higher salinity levels (80 mM of NaCl) were combined with different light conditions (fluorescent lamps, red–blue LED, red–blue–deep red LED). Purslane coped well with the salinity level under the two LED lighting regimes. The nutritional quality of this microgreen was improved as anti-nutritive compounds were lower when grown with LEDs and supply of NaCl. The study showed that it is possible to achieve high yields when growing purslane microgreens under saline conditions and an appropriate choice of light sources, although this was at the expense of some valuable plant pigments (chlorophylls, carotenoids, flavonoids).

2.4. Effects of Application of Different Substances

Stressful conditions can also be imposed by applying certain chemicals to plants. In particular, substances that mimic the action of plant hormones are the focus of attention. Gibberellic acid is known to regulate both vegetative and reproductive growth processes in plants. It thereby affects the quality of the product by enhancing its antioxidant status. Both the alteration of plant growth and developmental processes and the impact on the nutritional quality are very relevant for the tropical vegetable crop *Momordica charantia* (bitter gourd). Abbas et al. [9] conducted field trials with two varieties of bitter gourd exposed to five different concentrations of a commercial gibberellic acid product. They found that the exogenous application of the plant growth regulator at high concentrations enhances growth (e.g., increased length of petioles and internodes) and yield (increased fruit numbers, increased fruit weight) while decreasing the activity of several antioxidant enzymes at the same time.

In another contribution, Abbas et al. [10] investigated the effects of foliar spraying with seaweed extract on the productivity and quality of four onion cultivars. The bio-stimulant was applied at four concentrations, with the lowest concentration (0.5%) resulting in an increased yield, increased contents of some mineral nutrients and increased soluble solids of the bulbs. The highest concentration of the seaweed extract (3%) increased the concentrations of ascorbic acid in the bulbs as compared to those without the application of seaweed extract.

2.5. Grafting as a Method to Reduce the Impact of Abiotic Stress

Grafting is a commonly used method in overcoming abiotic and biotic stresses during the cultivation of fruit vegetable crops. The advantage of this cultivation technique is the combination of potential beneficial properties of two or more accessions in one plant.

Devi et al. [11] contributed a review dealing with the effects of grafting on the fruit maturity and quality of watermelons. The publication summarizes the results of research activities on the impact of grafting watermelon scions on different rootstocks, with a focus on the formation of hollow hearts and hard seeds, flesh firmness, total soluble solid content, pH, titratable acidity, lycopene content and concentration of the non-essential amino acid citrulline, which can be of relevance for the cardiovascular system.

2.6. Modulation by Storage Conditions

The impacts of post-harvest conditions on the quality of vegetables are represented as well. Wang et al. [12] combined elevated CO_2 pre-treatments and different packaging methods in order to assess the effects on different quality characteristics of green asparagus in cold storage. The authors showed that continuous application of elevated CO_2 reduced the decay of the asparagus spears to the greatest extent by inhibiting the microbial development. In general, elevated CO_2 application, either continuously or as a three-day pre-treatment, did not only reduce the microbial load and the respiration rate but also improved the sensory and nutritional quality of the green asparagus. In combination with modified atmosphere packaging, the pre-treatment with elevated CO_2 was able to preserve the visual quality and the fresh weight of the asparagus and reduce the development of an off-odor.

Funding: This research received no external funding.

Acknowledgments: I gratefully acknowledge all the authors that participated in this Special Issue.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Herms, D.A.; Mattson, W.J. The Dilemma of Plants: To Grow or Defend. *Q. Rev. Biol.* **1992**, *67*, 283–335. [CrossRef]
2. De Luca, A.; Corell, M.; Chivet, M.; Parrado, M.A.; Pardo, J.M.; Leidi, E.O. Reassessing the Role of Potassium in Tomato Grown with Water Shortages. *Horticulturae* **2021**, *7*, 20. [CrossRef]
3. Ellenberger, J.; Bulut, A.; Blömeke, P.; Röhlen-Schmittgen, S. Novel *S. pennellii* × *S. lycopersicum* Hybrid Rootstocks for Tomato Production with Reduced Water and Nutrient Supply. *Horticulturae* **2021**, *7*, 355. [CrossRef]
4. Schmidt, L.; Zinkernagel, J. Opportunities of Reduced Nitrogen Supply for Productivity, Taste, Valuable Compounds and Storage Life of Cocktail Tomato. *Horticulturae* **2021**, *7*, 48. [CrossRef]
5. Schmidt, L.; Zinkernagel, J. For a Better Understanding of the Effect of N Form on Growth and Chemical Composition of C_3 Vascular Plants under Elevated CO_2—A Case Study with the Leafy Vegetable *Eruca sativa*. *Horticulturae* **2021**, *7*, 251. [CrossRef]
6. Giménez, A.; Del Martínez-Ballesta, M.C.; Egea-Gilabert, C.; Gómez, P.A.; Artés-Hernández, F.; Pennisi, G.; Orsini, F.; Crepaldi, A.; Fernández, J.A. Combined Effect of Salinity and LED Lights on the Yield and Quality of Purslane (*Portulaca oleracea* L.) Microgreens. *Horticulturae* **2021**, *7*, 180. [CrossRef]
7. Corrado, G.; Vitaglione, P.; Chiaiese, P.; Rouphael, Y. Unraveling the Modulation of Controlled Salinity Stress on Morphometric Traits, Mineral Profile, and Bioactive Metabolome Equilibrium in Hydroponic Basil. *Horticulturae* **2021**, *7*, 273. [CrossRef]
8. Sica, P.; Galvao, A.; Scariolo, F.; Maucieri, C.; Nicoletto, C.; Pilon, C.; Sambo, P.; Barcaccia, G.; Borin, M.; Cabrera, M.; et al. Effects of Drought on Yield and Nutraceutical Properties of Beans (*Phaseolus* spp.) Traditionally Cultivated in Veneto, Italy. *Horticulturae* **2021**, *7*, 17. [CrossRef]
9. Abbas, M.; Imran, F.; Iqbal Khan, R.; Zafar-ul-Hye, M.; Rafique, T.; Jameel Khan, M.J.; Taban, S.; Danish, S.; Datta, R. Gibberellic Acid Induced Changes on Growth, Yield, Superoxide Dismutase, Catalase and Peroxidase in Fruits of Bitter Gourd (*Momordica charantia* L.). *Horticulturae* **2020**, *6*, 72. [CrossRef]
10. Abbas, M.; Anwar, J.; Zafar-ul-Hye, M.; Iqbal Khan, R.; Saleem, M.; Rahi, A.A.; Danish, S.; Datta, R. Effect of Seaweed Extract on Productivity and Quality Attributes of Four Onion Cultivars. *Horticulturae* **2020**, *6*, 28. [CrossRef]

11. Devi, P.; Perkins-Veazie, P.; Miles, C. Impact of Grafting on Watermelon Fruit Maturity and Quality. *Horticulturae* **2020**, *6*, 97. [CrossRef]
12. Wang, L.-X.; Choi, I.-L.; Kang, H.-M. Correlations among Quality Characteristics of Green Asparagus Affected by the Application Methods of Elevated CO_2 Combined with MA Packaging. *Horticulturae* **2020**, *6*, 103. [CrossRef]