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Editorial

Horticultural Crop Response to Different Environmental and Nutritional Stress

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Abstract: Environmental conditions and nutritional stress may greatly affect crop performance. Abiotic stresses such as temperature (cold, heat), water (drought, flooding), irradiance, salinity, nutrients, and heavy metals can strongly affect plant growth dynamics and the yield and quality of horticultural products. Such effects have become of greater importance during the course of global climate change. Different strategies and techniques can be used to detect, investigate, and mitigate the effects of environmental and nutritional stress. Horticultural crop management is moving towards digitized, precision management through wireless remote-control solutions, but data analysis, although a traditional approach, remains the basis of stress detection and crop management. This Special Issue summarizes the recent progress in agronomic management strategies to detect and reduce environmental and nutritional stress effects on the yield and quality of horticultural crops.

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1. Introduction

Food and agriculture systems may follow alternative pathways, depending on the evolution of a variety of factors, such as population growth, dietary choices, technological progress, income distribution, the state and use of natural resources, climatic changes and efforts to prevent and resolve conflicts. These pathways can and will be impacted by strategic choices and policy decisions. Swift and purposeful actions are needed to ensure the sustainability of food and agriculture systems in the long term [1].

Climate change is considered as one of the future challenges that either directly or indirectly affect all sectors negatively [2]. Environmental interactions also affect sectors that have a direct reliance on natural resources for production, highlighting their significance for national socio-economic development. The agriculture sector, in turn, has about 2.5 billion livelihoods that are dependent on it. The quality and yield of horticultural crops need to be improved for their production, cultivation management, and biotic/abiotic resistances. Biotic and abiotic factors are the main factors limiting production in agricultural systems [3,4]. Abiotic stresses such as temperature (cold, heat), water (drought, flooding), irradiance, salinity, nutrients, and heavy metals can strongly affect plant growth dynamics, increase crop yield losses and the yield and quality of horticultural products.

Such effects become more and more important in the course of global climate change. Water scarcity, climate change, and drought are the main hurdles in our efforts to make our agri-food systems resilient and sustainable [4]. Different strategies and techniques can be used to detect, investigate, and mitigate the effects of environmental and nutritional stress. Horticultural crop management is moving towards digitized, precision management through wireless remote-control solutions, but data analysis, although a traditional approach, remains the basis of stress detection and crop management.

2. Special Issue Overview

This Special Issue collects current research findings that deal with a wide range of topics to detect environmental and nutritional stress effects on the yield and quality of horticultural crops.

The effect of environment conditions (temperature, rainfall, altitude, soil types, hail) [5–9], nutritional strategies [5,6,10–14], water (stress, salinity) [5,8,12,15], container substrate of cultivation [16] on yield, yield traits and quality were analyzed in different crops in an open field [8,9,13,14,17] and greenhouses [5–7,10–12,15,16].

Different innovative strategies were presented that included protected structures, container type, cultivation techniques [5,10,16], symbiotic relationships [6,7], fertigation strategies [10] new agricultural management technologies (remote sensing, smartphone) [11] novel hybrids for breeding [12] spraying of Gibberellic acid [17], water supplies [8,15] and substrate [16] cover crops management [13] and stand reduction [9].

2.1. Nutrient Concentration of African Horned Cucumber (Cucumis metalliferous L.*) Fruit under Different Soil Types, Environments, and Varying Irrigation Water Levels*

This study was conducted during the 2017/18 and 2018/19 growing seasons, under the greenhouse, shade net, and open-space environment at the Florida science campus of the University of South Africa [5]. The aim was to determine the effect of different water stress levels, soil types, and growing environments (greenhouse, shade net, and open field) on the nutrient concentration of the African horned cucumber fruit. Total soluble sugars, crude proteins, β-carotene, vitamin C, vitamin E, total flavonoids, total phenols and micro-nutrients were analyzed. The results showed that African horned cucumber fruits are nutrient-dense when grown under moderate water stress treatment on a loamy or sandy loam substrate in shade-net and open-field environments. Quality parameters (total flavonoids, total phenols, micro-nutrients and vitamins metabolites) seem to be treatment-imposed. The data show that this crop can grow well under protected structures, which eliminates the potential damage caused by higher rainfall, hail, and extreme heat in summer.

2.2. Growth and Competitive Infection Behaviors of Bradyrhizobium japonicum and Bradyrhizobium elkanii at Different Temperatures

Growth and competitive infection behaviors of two sets of *Bradyrhizobium* spp. strains were examined at different temperatures to explain strain-specific soybean nodulation under local climate conditions [6]. Each set consist of three strains—*B. japonicum* Hh 16-9 (Bj11-1), *B. japonicum* Hh 16-25 (Bj11-2), and *B. elkanii* Hk 16-7 (BeL7); and *B. japonicum* Kh 16-43 (Bj10J-2), *B. japonicum* Kh 16-64 (Bj10J-4), and *B. elkanii* Kh 16-7 (BeL7)—which were isolated from the soybean nodules cultivated in Fukagawa and Miyazaki soils, respectively. The authors compared growth and infection behaviors at different temperatures in Japan (Fukagawa and Miyazaki soils) and elucidated the reason why the species-specific nodule compositions are present in the Fukagawa and Miyazaki soils and locations. The experiments performed in liquid cultures revealed better growth of *B. japonicum* at lower temperatures and *B. elkanii* at higher temperatures, and therefore it can be assumed that the temperature of soil affects rhizobia growth in the rhizosphere and could be a reason for the different competitive properties of *B. japonicum* and *B. elkanii* strains at different temperatures. In addition, competitive infection was suggested between the *B. japonicum* strains.

2.3. Effects of Fertigation Management on the Quality of Organic Legumes Grown in Protected Cultivation

The experimental trial was carried out in a protected cultivation certified organic farm in the province of Almería, South-East Spain on four legume cultivars of *Phaseolus* and *Pisum* [10]. The objective of the study was to determine the effects of two fertigation treatments, normal (T100) and 50% sustained deficit (T50), on the physico-chemical quality of legumes. The fertigation treatments had significant effects on the morphometric traits (width for mangetout and French bean; fresh weight for French bean; seed height for Pea cv. Lincoln). Furthermore, only French bean plants had significantly lowered productivity under 50% fertigation conditions. Furthermore, mangetout became the highest source of total soluble solids, reaching higher content at 50% fertigation treatment. Fertigation treatments did not significantly affect the antioxidant compounds (total polyphenols and ascorbic acid), minerals and protein fraction contents of the legumes studied.

2.4. Latitudinal Characteristic Nodule Composition of Soybean-Nodulating Bradyrhizobia: Temperature-Dependent Proliferation in Soil or Infection?

To examine the possible reasons for the temperature-dependent distribution of soybean-nodulating rhizobia, competitive inoculation experiments at different temperatures were conducted [7]. The study chose three locations Fukagawa, Matsue and Miyazaki which are considered to have different climatic conditions in Japan. The aim was to elucidate the possible reasons for the latitudinal characteristic distribution of soybean-nodulating rhizobia in local climate conditions. Rainfall might affect the soil conditions during the winter season, though the difference in the soil storage did not seem to be serious on the composition of rhizobia and the difference in rainfall would not significantly affect the nodule composition. The most interesting result was that the soil temperature mainly affected the dominant nodule composition in the different environmental conditions.

2.5. A Novel Method for Estimating Nitrogen Stress in Plants Using Smartphones

The objectives of the research were to (i) test the hypothesis that the ratio of blue light reflectance to that of combined reflectance in the visible band can be used as an index for N stress, (ii) study the association between the N stress index and the physiological pathways in plants, and (iii) develop a smartphone application to measure the N stress index in species with differences in plant architecture [11]. The experiment was conducted in a greenhouse at Purdue University, West Lafayette, IN, USA. Nitrogen stress was provided by supplying a fertilizer solution with an EC of 0.75 $dS \cdot m^{-1}$ and maintaining a θ level of 0.48 $m^3 \cdot m^{-3}$. The study developed an index, calculated as the ratio of reflectance of blue relative to the reflectance of combined wavelengths in the visible wavelengths band. The index value decreased when plants were exposed to nitrogen stress relative to optimal conditions. Furthermore, the index value decreased gradually with increasing N stress in plants. Therefore, the continuous measurement of the index can aid in the timely detection of N stress in plants.

2.6. Cucurbita Rootstocks Improve Salt Tolerance of Melon Scions by Inducing Physiological, Biochemical and Nutritional Responses

An experiment was conducted to evaluate whether grafting with hybrid *Cucurbita maxima* × *Cucurbita moschata* rootstocks could improve the salt tolerance of melon and to determine the physiological, biochemical, and nutritional responses induced by Cucurbita rootstocks under hydroponic salt stress [12]. Results indicated that the shoot and root growths of grafted and nongrafted melon plants were detrimentally affected by salt stress. Significant reductions were recorded in some agronomic and physiological plant traits. Susceptible plants responded to salt stress by increasing leaf proline and malondialdehyde (MDA), ion leakage, and leaf Na^+ and Cl^- contents. The highest plant growth performance was exhibited by Citirex/Nun9075 and Citirex/Kardosa graft combinations. These Cucurbita cultivars had a high rootstock potential for melon, and their significant contributions to salt tolerance were closely associated with inducing the physiological and the biochemical responses of the scions. These traits could be useful for the selection and breeding of salt-tolerant rootstocks for sustainable agriculture in the future.

2.7. The Effects of Gibberellic Acid and Emasculation Treatments on Seed and Fruit Production in the Prickly Pear (Opuntia ficus-indica (L.) *Mill.) cv. "Gialla"*

The author tested the application of two methods (injection and spraying) of gibberellic acid (GA_3) on the prickly pear cactus both at pre- and post-blooming in order to obtain well-formed seedless fruits in emasculated flowers [17]. The experiments were conducted in the Apulia region, Italy. Different application methods (injection and spraying) and concentrations of GA_3 (0, 100, 200, 250, and 500 ppm) combined with floral-bud emasculation were applied to a commercial plantation to evaluate their effects on the weight, length, and diameter of the fruits, total seed number, hard-coated viable seed number, and seed weight per fruit. The application of 500 ppm GA_3 sprayed on emasculated floral buds was the most effective method for reducing the seed numbers of prickly pear fruits (−46.0%). The injection method resulted in a very low number of seeds (−50.7%) but produced unmarketable fruit. The spraying of the GA_3 (both at low and high levels) enhanced the growth performance of all analyzed variables of the treated fruits, while the application of these treatments in an industrial-scale requires support to evaluate the processes.

2.8. Water Use and Yield Responses of Chile Pepper Cultivars Irrigated with Brackish Groundwater and Reverse Osmosis Concentrate

Freshwater availability is declining in most of the semi-arid and the arid regions across the world [15]. The study evaluated the effects of natural brackish groundwater and RO concentrate irrigation on the water use, leaching fraction, and yield responses of Chile pepper cultivars (*Capsicum annuum* L.). The study was conducted in a greenhouse located at the New Mexico State University (NMSU). Saline irrigation caused a reduction in the water uptake of the Chile peppers and increased LFs. The four saline water treatments used for irrigation were tap water with an electrical conductivity (EC) of 0.6 dS m^{-1} (control), groundwater with EC 3 and 5 dS m^{-1}, and an RO concentrate with EC 8 dS m^{-1}. The WUE was not substantially different but decreased significantly in the other two higher salinity treatments. Therefore, irrigating Chile peppers with up to 3 dS m^{-1} brackish water could be possible by maintaining appropriate leaching fractions to sustain Chile pepper production in freshwater-scare areas where brackish groundwater is the only available source of irrigation. The yield response curves showed that the yield reductions in the Chile peppers irrigated with natural brackish water were less, compared to those of NaCl-dominant solution studies. Low yield reductions could be related to significant Ca^{2+} concentrations in the brackish groundwater and RO concentrate.

2.9. Alterations in the Chemical Composition of Spinach (Spinacia oleracea L.*) as Provoked by Season and Moderately Limited Water Supply in Open Field Cultivation*

The study shows the relationship of the irrigation water supply with that of the chemical composition of the Spinach (*Spinacia oleracea* L.) [8]. Trials of the study recorded a slight effect on the chemical composition of the plant from providing a moderate water supply which ultimately influenced the product quality of field-grown spinach plants. In the reduced water supply treatment, the total amount of supplied water, including both irrigation and natural precipitation, amounted to 90%, 94% and 96% in 2015, 2016 and 2017, respectively, of the full optimal water supply treatment. The study was carried out on Spinach cv. 'Silverwhale' grown under open field conditions at Geiseheim University, Germany. The chemical composition of both the dry and the fresh biomass of spinach was shown to be strongly influenced by the climatic conditions and/or the water supply. Fresh biomass-related levels of ascorbic acid, potassium, nitrogen, phosphorous as well as total flavonoids and carotenoids increased upon limiting the water supply. Considering the composition of the dry biomass itself, authors demonstrated that even mild water supply reductions led to significant increases of inositol, zinc and manganese levels, while malic acid, phosphate and chloride levels decreased. The nutritional composition of spinach was sensitive to even moderately reduced water supply, but the overall quality of fresh spinach did not suffer regarding the levels of health-promoting constituents such as minerals, trace elements, flavonoids and carotenoids.

2.10. Container Type and Substrate Affects Root Zone Temperature and Growth of 'Green Giant' Arborvitae

The objective of this research was to evaluate the combined effects of the container type and the substrate on RZT and growth of *Thuja standishii* × *plicata* 'Green Giant' [16]. Two separate studies were conducted concurrently at the Tennessee State University and the Auburn University Ornamental Horticulture Research Center, USA. Trade gallon arborvitae were transplanted into black, white, or air pruning containers filled with pine bark (PB) or 4 PB: 1 peatmoss (*v:v*) (PB:PM). Plants grown in PB:PM were larger and had greater shoot and root biomass than plants grown in PB, likely due to the increased volumetric water content. Plant growth response to container type varied by location, but white containers with PB:PM produced larger plants and greater biomass compared with the other container types. Root zone temperature was greatest in black containers and remained above 38 °C and 46 °C for 15% and 17% longer than white and air pruning containers, respectively. Utilizing light color containers in combination with substrates containing peatmoss can reduce RZT and increase substrate moisture content thus improving crop growth and quality.

2.11. Effects of Non-Leguminous Cover Crops on Yield and Quality of Baby Corn (Zea mays L.*) Grown under Subtropical Conditions*

The objective of this study was to evaluate the effects of non-leguminous cover crops and increments in chopping time versus Days After Planting (DAP) on the yield and quality of no-till baby corn (*Zea mays* L.) [13]. The experiment was carried out during kharif seasons under the subtropical climatic conditions. The experiment was conducted at the Punjab Agricultural University, Ludhiana, India. Three cover crops (pearl millet (*Pennisetum glaucum* L.), fodder maize (*Zea mays* L.), and sorghum (*Sorghum bicolor* L.)) and the control (no cover crop) were in the main plots and chopping time treatments (25, 35, 45 days after planting (DAP)) in the subplots. The yield (cob and green fodder yield) and dry matter accumulation of baby corn following cover crop treatments were significantly higher than the control (no cover crop) and improved with increment in chopping time. Increment in chopping time (from 25 DAP to 45 DAP) had a significant effect on the protein and sugar content of the baby corn cob. Chopping of cover crops at 45 DAP showed the highest yield and dry matter. Non-leguminous cover crops and their times of chopping evaluated in this study could be used for a sustainable maize crop production system to improve baby corn growth and yield, baby corn quality, and topsoil quality.

2.12. Effect of Stand Reduction at Different Growth Stages on Yield of Paprika-Type Chile Pepper

The goal of this study was to understand how a simulation of population losses by four levels of stand reduction at three different growth stages affected the yield and yield components of the paprika-type red Chile [9]. Two trials, one per year, were conducted in southern New Mexico. 'LB-25', a standard commercial cultivar, was direct seeded on 29 March 2016 and 4 April 2017. Field experiments were conducted at the New Mexico State University, USA. Plants were thinned at three different growth stages; early seedling, first bloom, and peak bloom at four different levels at each phenological stage: 0% stand reduction (control; ~200,000 plants ha^{-1}), 60% stand reduction (~82,000 plants ha^{-1}), 70% stand reduction (~60,000 plants ha^{-1}), and 80% stand reduction (~41,000 plant ha^{-1}). The timing of stand reductions (growth stage) for paprika-type Chile did not impact the marketable red yields. Paprika-type Chile has some capacity to recover and compensate for stand reduction losses. Data show that a farmer could lose up to 70% of their paprika-type Chile stand due to hail damage and experience minimal to no impact on their yields. Furthermore, the paprika-type Chile crop losses can be estimated based on percentage of stand losses instead of growth stage.

2.13. Fertilization and Soil Nutrients Impact Differentially Cranberry Yield and Quality in Eastern Canada

The objective of the research activities was to support site-specific nutrient management decisions in cranberry agroecosystems [14]. A 3-year trial was conducted on permanent plots at four production sites in Quebec, Canada. This paper quantified the trade-off between berry yield and quality as driven primarily by N fertilization. Berry yield was closely related to the number of fruiting uprights (r = 0.92), berry counts per fruiting upright (r = 0.91), number of reproductive uprights (r = 0.83), and fruit set (r = 0.77). Nitrogen increased berry yield nonlinearly but decreased berry firmness, total anthocyanin content (TAcy), and total soluble solids content (°Brix) linearly, indicating a trade-off between berry yield and quality. Fertilizer dosage at a high-yield level ranged between 30 and 45 kg N ha^{-1} in both conventional and organic farming systems. Berry yield could be predicted most accurately from berry counts per fruiting upright. Nitrogen fertilization increased berry yield nonlinearly and decreased fruit quality-based indices in a linear trend. As shown by redundancy analysis (RDA), cranberry performance was related to soil pH and soil test nutrients. The K and Ca were negatively correlated between them, indicating an upper limit for K additions. The RDA indicated close relationships between cranberry performance indices and soil properties, and thus supported the need for further soil test calibration.

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