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Editorial

# Photosynthetic Adaptability of Crops under Environmental Change

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## 1. Introduction

Since it evolved, photosynthesis has been and will continue to be one of the factors that most define the current way of life on Earth, not only for plants but also for humans. Global climate change has recently begun causing anomalies, meaning that, measured on an evolutionary scale, adaptions have to occur faster than ever to contend with changes in the environment [1,2]. Both photosynthetic microorganisms and higher plants are challenged by biotic and abiotic factors that require short-term acclimation and longer-term adaptations [3]. The aim of the adapted forms and mechanisms realized at different levels, such as genes, molecules, cell organelles, cells, tissues, organs, individuals, and populations, is to maintain photosynthetic efficiency as high as possible. Any factor—be it water deficiency, drought, flooding, cold, heat, ozone, UV radiation, nutrient deficiency/excess, viral infection, etc.—that reduces the intensity of the photosynthetic processes over a long or short period of time may also induce light stress, which can cause irreversible damage through potential free radicals [4]. Facing rapidly changing and complex situations is a great challenge both natural vegetation, whether aquatic or terrestrial, as well as for cultivated crops. These processes can also be important for the survival for the human race [5]. The works published in this Special Issue provide an overview of the wide range of harmful environmental factors that can influence photosynthetic processes, and also present the mechanisms plants use to cope with these stressors.

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## 2. Recent Findings

Low temperatures number among the most important environmental factors that can hinder the spread of plants. There are two primary reasons for this: On the one hand, every plant has a given temperature optimum, to which it has adapted through evolution or, in the case of cultivated plants, breeding. On the other hand, partly as a result of global climate change, sudden spells of cold weather can often occur, which can cause acute damage to plants. Due to its complexity, several elements of the photosynthetic apparatus are temperature-sensitive and cannot tolerate conditions that are less than optimal. Consequently, research that examines how plants respond to low temperatures is of great importance. Strawberries (*Fragaria* × *ananassa* Duch.) are one of the most popular cultivated crops worldwide. However, most strains are cold sensitive and low temperatures can cause a substantial reduction in the quantity and quality of their fruit. In a recent study, Jiang and co-workers demonstrated that, at the seedling stage, short-day strawberry varieties exhibited better tolerance to cold than long-day varieties, when exposed to varying degrees of short-term (12 h) low-temperature stress [6]. The photosynthetic performance of long-day strawberries also begins to decline more significantly at higher temperatures when compared to short-day varieties. The authors also demonstrated how various non-destructive diagnosis tools could be used as to distinguish different levels of low-temperature stress, and to characterize the cold tolerance of the different strawberry cultivars, including: intercellular $CO_2$ concentration; apparent quantum yield, one of the chlorophyll-a fluorescence-induction parameters determined using the JIP test; the quantum yield for reduction in end electron acceptors at the PSI acceptor side and the performance index on an absorption basis; and certain solar-induced chlorophyll fluorescence parameters. Their results also confirmed that combining various physiological parameters is a more reliable way of describing the stress state of the plants than using single indices.

In addition to temperature stresses, drought is another harmful abiotic stressor causing substantial reductions in crop yields around the world. Furthermore, climate forecasts for the coming decades predict more and more periods of severe water deficit in many agricultural areas. Drought is one of the most common causes of forest dieback worldwide. Development of drought-tolerant genotypes is of fundamental importance in terms of future crop production. However, it has also been found that in perennial species, such as eucalyptus, fast-growing genotypes usually exhibit lower drought tolerance, while drought-tolerant genotypes often show lower productivity than expected. A recently published work by Corrêa and co-workers, examined the possible use of morphological, nutritional, and physiological traits as biomarkers for tolerance to water deficit in Eucalyptus plants [7]. They used several criteria for the applied biomarkers, such as easy access, heritability, and accuracy. They found various morphological, nutritional, and physiological phenotypic traits that occurred under drought conditions and which could be efficiently used for selection of water-deficit-tolerant plants in early selection in Eucalyptus breeding [7].

The results presented in another work by Caetano-Madeira and co-workers also supported findings related to the structural and physiological adjustment processes in Eucalyptus genotypes with different levels of tolerance to osmotic stress [8]. Susceptible genotypes could be characterized with a more pronounced decrease in allometric traits such as stem diameter and leaf and stem dry weight. Furthermore, although a significant genotype–nutrient content interaction was also detected, calcium and boron were generally higher in the dieback-tolerant genotypes. In addition to the basic agronomical parameters, water deficit also caused significant changes in the plants' metabolic profile [8].

In nature, environmental stressors rarely appear on their own, and the combined effects of several damaging factors, which can strongly influence one another, must be taken into account. Although it may occasionally happen that defense processes triggered by one stressor may partially help prevent the harmful effects of a different harmful environmental factor, it is usually the case that stressors that occur at the same time amplify each other. It is for this reason that studies which examine responses to combined stressors are very important.

Heavy metal contamination of the soil causes many different kinds of problems, both from the point of view of crop production and food safety. Kavian and co-workers investigated the combination of cadmium toxicity and drought stress in the economically important crop plant, maize (*Zea mays* L.) [9]. The combined application of drought and cadmium caused increased the negative effects faced by the plant, which was manifested in several agronomically important parameters, such as plant height and produced biomass. However, treatments with certain microbes, such as the plant growth-promoting Rhizobacterium *Bacillus paralicheniformis* or the plant growth-promoting fungus *Trichoderma asperellum*, successfully alleviated the negative effects of stress on plant health. The molecular mechanisms behind these protective effects are probably related to enhanced antioxidant activity, leading to lower level of oxidative stress. Furthermore, these microbes could efficiently reduce the cadmium accumulation in the plant's shoots, though not in its roots. The data presented by this team of researchers may contribute to the effective utilization of microorganisms for permanent phytostabilization in arid and semiarid regions contaminated with cadmium, and to produce sustainable food under drought conditions [9].

While certain microbes can be used to promote plant growth and protection plants against harmful environmental conditions, many others act as pathogens, causing dramatic losses in crop production and the quality and safety of the food produced. For example, grape powdery mildew (*Erysiphe necator*) is a key fungal pathogen, often causing serious problems in viticulture, such as substantial yield losses. Generally, various fungicides can be applied to control this infection; however, mainly for reasons of food safety, using environmentally friendly methods and products is becoming more and more important. Horticultural oil, for example, can be used to efficiently control a wide range of insects and pests with minimal contamination. In a recent study published by Pálfi and co-workers, high-purity paraffin oil was tested on grapevine against grape powdery mildew [10]. Spraying with mineral oil inhibited the spread of grape powdery mildew; however, this treatment may also have phytotoxic effects manifesting as the impairment of photosynthetic performance and partial yield loss. Therefore, further research is necessary to optimize the potential use of mineral oil as a protective material and its potential phytotoxic effects, which may depend on the environmental conditions and the genotype.

## 3. Conclusions and Future Perspectives

Since photosynthetic efficiency is one of the factors most critical for crop production, investigating how it can be maintained is of particular importance. It is also important to study the effects of individual stressors, not only separately but also together, recognizing how they interact with each other, as often happens in nature. In the future, methods that are able to reduce the effects of individual stressors, in an environmentally friendly but highly efficient way, will play an increasingly important role. In order to be able to use them, however, the adaptive mechanisms of plants must be much better understood.

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