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Factors Hindering Crop Biomass Production: Possible Tools to Overcome Abiotic Stress in Plants

Forni C*
Department of Biology, University of Rome Tor Vergata, Italy

***Corresponding author:** Cinzia Forni, Department of Biology, University of Rome Tor Vergata, Via della Ricerca Scientifica, 00133 Rome, Italy

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Editorial

In the Anthropocene Era climate changes, have severe impacts on important resources for agriculture, such as soil and water that have a critically pivotal role. For the production of healthy plant biomass it is necessary the presence in the soils of appropriate levels of nutrient and organic matter, a good soil structure and thickness to store adequate amount of water for plants, together with the absence of toxic compounds [1]. Any modification of these resources may impose severe constrains on plant growth, which cause loss of crop yield [1-2]. Beside changes of seasonal precipitation patterns and temperatures, soil degradation can decrease the cultivable areas by turning fertile fields to marginal lands, thus affecting this already grim scenario.

The term abiotic stress is commonly referred to the environmental stresses (e.g. flooding, drought, salt, high temperatures, etc.) that have an impact on plant performance by severely affecting growth and development. Such unfavourable environmental changes together with an increasing global population enhance the need for the development of more productive and stress-tolerant crops.

Environmental stresses can be transient, i.e. temporally limited temperature extremes or drought phases. After a stress has ended, plants may be able to recover from stress and reset their metabolism to growth and reproduction modes; but the recovery may not be always complete. In fact, even short-term environmental stress can have long-lasting effects on the plant. The comprehension of how plants, after stress imposition, are able to recover by re-establishing homeostasis and then maintain such physiological steady state, necessary for growth and completion of the life cycle in the new environment, is fundamental. During the past decades, plant scientists recognized the importance of the studies experimentally targeted to the identification of cell-based mechanisms that are essential determinants of stress tolerance [2,3]. The results have demonstrated that successful plant defences against abiotic stresses are depending on a large reprogramming of gene expression through the regulation of transcription, which can elicit a rapid and appropriate response to stress, i.e. the key for plant survival [2,3]. The identification of genes in plants, which expression is altered in response to abiotic stress, lead to the development of stress resistant genotypes both through breeding program and transgenic technology [4,5,6]. Several genes, involved in different metabolic pathways, could be genetically modified, such as those involved in photosynthesis, osmoprotectants and antioxidant production and synthesis of protective proteins, as well as transcription factors [4-7]. Consequently, in several studies the development of transgenic plants characterized by elevated/good level of stress resistance has been reported.

An alternative approach to tackle the issue of improving stress tolerance is plant acclimation to the stress conditions. The principle of acclimation is based on the genetic plasticity of the plants, which plays a fundamental role in conferring different degrees of tolerance that strongly depend on the effectiveness of stress response mechanisms. In non-tolerant species, a gradual adaptation to stress is required in order to better counteract the negative effects of stress: this can be obtained through the expression of the genes responsible for the defence to such conditions, thus leading to a better performance [8]. Even though the acclimation has been demonstrated to ameliorate the tolerance in many herbaceous species, further studies are needed to better understand the mechanism related to the phenomenon, since plant acclimation to some abiotic stress condition may require a response that needs to be tailored to the specific environmental stress to which plant is exposed [9].

Literature reports suggest that after exposure to stressful conditions, plants can store information about a past stress event, which may be beneficial by preparing them when they are subsequently exposed to the same or similar stress. This represents the principle of the priming [10]. Seed priming is a pre-sowing treatment protocol that foresees the soaking of the seeds in different agents, acting as elicitors, for a specific period, followed by seed drying. This allows the partial hydration of the seeds avoiding the radicle emergence [11]. Therefore, a time gap separates the end of the priming stimulus, i.e. soaking of the seeds in priming solution, and the beginning of the triggering stimulus, i.e. exposure to stress conditions, nevertheless the information about the priming experience is stored during the lag phase until the stress begins. The “priming memory” will stimulate stress responses and possibly induce a cross-tolerance to abiotic stress [10]. Several seed priming treatments have been investigated, including those against biotic and abiotic stresses [12,13]. The duration of the priming, memory is depending on several parameters, i.e. the species and even the genotype, or priming protocol (i.e. exposure time, the priming stimulus and the stimulus intensity). Mechanisms of epigenetic memory in plants have been reviewed by Iwasaki and Paszkowski [14].

Biological tool can be also applied to ameliorate stress tolerance, like the utilization of Plant Growth Promoting Bacteria (PGPB) [3]. There are many bacterial genera that are included in the PGPB [3]. These bacteria can either directly or indirectly facilitate plant growth in optimal and sub-optimal and even stress conditions [3]. Their effects on plants are due to the production of different compounds

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that are beneficial for the plant, such as phytohormones (i.e. auxin, cytokinins and gibberellin), polysaccharides and siderophores; moreover, some of them fix nitrogen, and solubilize organic and inorganic phosphate [15]. Such activities can influence the osmotic balance and ion homeostasis through modulation of gene expression, protein function, and synthesis of metabolites in plants. For example, salt plant tolerance is improved by bacterial production of osmolytes, like proline, glycine betaine, and soluble sugars [3]. The modulation of plant hormone levels by PGPB can be also involved in stress response [3]. For example, stress ethylene-mediated growth inhibition can be counteracted by some species of PGPB possessing an enzyme called ACC deaminase (1-Aminocyclopropane-1-Carboxylate deaminase), which is the enzyme that hydrolyzes ACC (the immediate biosynthetic precursor of ethylene) to ammonia and α-ketobutyrate [3,16]. ACC deaminase-containing PGPB increased the uptake of K^+ and the root to shoot K^+ flow, while lowering the Na^+ flow [3].

So far, the data present in the literature provide evidences and suggest different approaches that can be utilized as a tool to improve crop tolerance. There is no doubt that these approaches perform well in laboratory, growth chamber or greenhouse studies, however quite a lot of work remains to be done, such as extensive trials in field conditions, in order to confirm the achievement of successful solutions to upcoming environmental challenges.

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