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Quality Improvement in Cole Crops for Abiotic Stresses : A Review

Abdul Shamad, Vijay Bahadur, Devi Singh, VM Prasad

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ABSTRACT

Reductions in crop yields brought about by abiotic stress are expected to increase as climate change, and other factors, generate harsher environmental conditions in regions traditionally used for cultivation. Although breeding and genetically modified and edited organisms have generated many varieties with greater abiotic stress tolerance, their practical use depends on lengthy processes, such as biological cycles and legal aspects. On the other hand, a non-genetic approach to improve crop yield in stress conditions involves the exogenous application of natural compounds, including plant metabolites. In this review, we examine the recent literature related to the application of different natural primary (proline, L-tryptophan, glutathione, and citric acid) and secondary (polyols, ascorbic acid, lipoic acid, glycine betaine, α-tocopherol, and melatonin) plant metabolites in improving tolerance to abiotic stress. We focus on drought, saline, heavy metal, and temperature as environmental parameters that are forecast to become more extreme or frequent as the climate continues to alter. The benefits of such applications are often evaluated by measuring their effects on metabolic, biochemical, and morphological parameters in a variety of crop plants, which usually result in improved yields when applied in greenhouse conditions or in the field. As this strategy has proven to be an effective way to raise plant tolerance to abiotic stress, we also discuss the prospect of its widespread implementation in the short term.

Keywords Abiotic stress, Cole crop, Improvement. Biological Cycles Stress condition.

INTRODUCTION

Abiotic stress is one of the most important problems currently faced by agriculture (Bisbis *et al.* 2018). It causes serious losses in crop production worldwide and reduces planted acreage. Amidst a growing population and climate change, this scenario becomes increasingly complex (Bulgari *et. al.* 2019). Because the world population is forecast to increase from 7 to 9–10 billion people by 2050, an increase of between 60 and 110% in global food production will be required (Mittler *et.al.* 2006). Arable lands are also affected by migration to cities; as urban areas expand, they encroach more into surrounding, often fertile land, which is another factor that push-

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Abdul Shamad[1]*, Vijay Bahadur[2], Devi Singh[3] , VM Prasad[4]
[1] PhD. Scholar/Teaching Associate, [2] Associate Professor & Head, Associate Professor, [4]Professor

Department of Horticulture,
Sam Higginbottom University of Agriculture, Technology and Sciences, Naini Prayagraj 211007, India
Email : abdulshamad12@gmail.
*Corresponding author

es agriculture into areas that are less-suited to crop cultivation (Parajuli *et al.* 2019). In today‘s climate change scenarios, crops are exposed more frequently to episodes of abiotic stresses. It is estimated that abiotic stress such as drought, salinity and extreme temperatures, which usually cause primary crop losses worldwide, lead to an average yield loss of >50% for most major crop plants (Rivero *et al.* 2014). It is important to understand the nature and sources for abiotic stresses that affect vegetables. In addition, with improved understanding, options for better management or resistance become available (Abu Qamar *et al.* 2009).

Cole crop represents a group of important food crops that includes cabbage (*B. oleracea* L. var. capitata), cauliflower (var. botrytis), broccoli (var. italica), kale (var. acephala), Chinese kale (var. alboglabra), Brussels sprouts (var. gemmifera) and kohlrabi (var. gongylodes) amongst others. *B. oleracea* (Ahanger *et al*. 2017) cultivars are generally considered to be cool-season crops and therefore would be expected to suffer during periods of higher temperature, 2 but they may also be sensitive to extremes of drought, water logging, salinity, cold or other sources of abiotic stress (Antony *et al.* 2010).

Harvested vegetables can be potentially exposed to numerous abiotic stresses during production, handling, storage and distribution (Atkinson and Urwin 2012). When the abiotic stress is moderate or severe, quality losses almost always are incurred at market. Hence, understanding of effects of field abiotic stresses on postharvest stress susceptibility will become more important since postharvest stresses limit the storage and shelf life potential of vegetables (Banerjee *et. al.* 2017). In recent years, advances in physiology, molecular biology and genetics have greatly improved our understanding of crops response to these stresses and the basis of varietal differences in tolerance (Batool *et al.* 2013).

Pre-harvest stresses influence postharvest abiotic stress

It is important to characterize the relationship between pre-harvest abiotic stresses occurring during production and postharvest abiotic stresses that the vegetable is exposed after harvest, during storage and distribution (CMhen *et al*. 2014), since the solution to these different problems will be best resolved by focusing on pre-harvest or postharvest abiotic stress amelioration, respectively (Giuffrida *et al*. 2013).

Extremes temperature

If the temperature drops below 15°C plants experience low temperature stress and if it is above 45°C, plants are subjected to high temperature stress (Hadi *et al*. 2014). High temperature stress has a wide range of effects on plants in terms of physiology, biochemistry and gene regulation pathways (Hnilickova and Duffek 2004). Brief exposure of plants to high temperatures during reproductive stage can accelerate senescence, diminish fruit, seed set and reduce yield (Jamil *et al.* 2006). In addition, heat stress problems also make the plant susceptible to pests and other environmental problems. Seed germination can be reduced or even inhibited by high temperatures, depending on the species and stress level (Jamil *et al.* 2007). Antioxidants present in vegetable crops can also be altered by exposure to high temperatures during the growing season (Kage *et al*. 2004). If the pre-harvest temperature leads to chilling induced injury in the field, then susceptibility to postharvest chilling injury can be increased (Lin *et al.* 2015). Therefore, the level of the pre-harvest temperature extreme will be a determinant as to if the exposure will have positive or negative effects on postharvest stress sensitivity (Monaghan *et al.* 2013).

Temperature during the growth period has been shown to impact upon the growth of *B. oleracea* crops (Rodriguez *et al.* 2015). For example, cabbage plants have been found to show reduced disease tolerance and lower yields at high temperatures. Both low and high temperatures have been reported to affect stomatal conductance and fresh weight in cabbage and kale, but with kale appearing more susceptible to changes in air temperature than cabbage (Shannon *et al.* 2000).

Drought

One-third of the world’s population resides in water-stressed regions, with elevated CO_2 levels in the atmosphere and climatic changes predicted in the future, drought could become more frequent and severe (Wahid *et al.* 2014). It is predicted that water deficit will continue to be a major abiotic factor affecting global crop yields. Soil moisture deficit influences the crop yield by (i) reduced canopy absorption of photosynthetically active radiation, (ii) decreased radiation-use efficiency and (iii) reduced harvest index (Zhu *et al.* 2011). The occurrence of drought conditions during production of vegetable crops is becoming more frequent with climate change patterns. There have been both positive effects reported for field water deficits (stress) in root vegetables (Raza *et al*. 2019). The negative affect associated with water deficits is the case of root vegetables, such as carrot, where pre-harvest water stress (watering to 25-75% of soil water field capacity) can weaken the cells, resulting in higher membrane leakage (cell damage) and consequently greater weight loss in storage (Dhankher and Foyer 2018).

Drought stress in cauliflower led to reduced seed germination, shoot and root length and biomass, stomatal conductance, transpiration, curd growth and dry matter. Chinese kale, both water deficit and water logging led to reduced leaf area, fresh and dry weight and leaf number, with drought leading to darker leaves and closed stomata.

Many study had showed that the drought, flooding, salinity, heat and cold stress tolerance of *B. oleracea* lines of the Vegetable Genetic Improvement Network (VeGIN) *B. oleracea* Diversity Fixed Foundation Set (DFFS) (Raza *et al.* 2019). This set represents a group of genetically fixed, double haploid (DH) lines which have been chosen to maximize both genetic and morphological variability and have been obtained from a wide range of geographical sources (Walter *et al.* 2013). The group of lines tested included cabbage (*B. oleracea* L. var. capitata), cauliflower (var. botrytis), broccoli (var. italica), kale (var. acephala), Chinese kale (var. alboglabra) and kohlrabi (var. gongylodes). No DH lines of Brussels sprouts (var. gemmifera) were available at the time of the study. These plants have been developed as DH lines to eliminate the heterogeneity and heterozygosity commonly encountered with gene bank lines, allowing the same genotype to be tested against different stresses (Dong *et al.* 2020). To our knowledge this is the first time that a fixed diversity set has been screened against multiple stresses in this manner.

Light

Head/ curd size is smaller when the crop is grown under ambient low light levels, such as in the early spring season in northern latitudes and since surface area to volume ratio is greater in smaller fruits, susceptibility to postharvest desiccation stress would increase (Pathak *et al.* 2018). When lettuce is grown under low light which is sub optimal for photosynthetic activity, shelf life of fresh cut lettuce is much shorter than lettuce produced under optimal light conditions because it is subjected to mechanical stress. Low light also results in lower levels of ascorbate in many greenhouse-grown vegetables, which would render them less fit to deal with postharvest stresses since ascorbate contents are general directly proportional to relative levels or stress tolerance (Scheben *et al*. 2016).

Management of abiotic stress in cole crop

The horticulture sector is therefore actively seeking for new agronomic tools that are able to contrast the negative effects of environmental stresses, while maintaining the overall sustainability and quality of the production. Among those new bio-technological innovations, biostimulants have gained increased attention in the last decade also because of their capability to exploit agricultural, urban, and industrial waste materials in a perspective of circular economy. The definition of plant biostimulants has been the object of an in-depth discussion mainly driven by regulatory purposes (Seymen 2021) EU regulations currently focus on a claim-based definition of biostimulants, and thus they are defined as substances able to improve one or more of the following plant or plant rhizosphere characteristics: (i) nutrient use efficiency, (ii) tolerance to abiotic stresses, (iii) quality traits, and (iv) availability of confined nutrients in the soil or rhizosphere. This legal definition includes many substances, which can be distinguished into two main categories: Microbial and non-microbial biostimulants (Chatterjee and Solankey 2015). The timing of the bio-stimulant application with regard to the development of the stressful condition plays a crucial role for the successful application of these products. A plant bio-stimulant containing compounds that have an anti-stress effect can be applied when the stress occurs or immediately before (this is the case of proline-containing products, for instance). Differently, other biostimulants that are able to trigger a systemic defense response (i.e., against reactive oxygen species generated by stress) have to be applied in advance in order to achieve a so-called "priming" effect. It is therefore possible to distinguish between preventive, curative, and recovery strategies for the effective use of biostimulants against abiotic/ environmental stresses (Mallya *et al.* 2016)

CONCLUSION

Plants are frequently exposed with different biotic and abiotic stresses, which cause important disaster over crop yields around the world. Thus, it might make logical that understanding stress tolerance in achievements for nourish and feed humanity through improving crop plant yield and potential under stressful environmental condition. Biostimulants are currently defined and classified by their effects on plants. The claim of "enhanced tolerance to abiotic stress" implies, therefore, that an objective evaluation of biostimulant efficacy in reducing the negative effects of stress in plants is achieved.

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