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Thermo-protectants: Boosters for Enhancing Thermotolerance and Yield in Mung Bean

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Abstract

Mung bean is an important pulse crop well adapted within the range of 27-30˚C temperature for optimum growth. However, mung bean crop experiences abnormally high temperature (> 40˚C) at the reproductive stage that accelerates flowers and pod shedding results in poor yield during the summer season and reduction is severe when the crop sowing is delayed. However, thermo-protectants such as, phytohormones, osmolytes and signalling molecules exogenous application significantly enhance thermo-tolerance and yield of mung bean under heat stress conditions. Thus, the present article has been framed to throw light on the protective role of major thermo-protectants which are effective to boost flowering and podding and yield by improving thermo-tolerance in mung bean.

Keywords: Heat Stress, Mung Bean, Thermo-protectant, Thermotolerance and Yield

Introduction

Mung bean (*Vigna radiata* (L.) Wilczek) has a recognizable status among pulses, due to its shorter life cycle, high daily productivity and multiuse and contributes 11% to the country's total pulse production. Mung bean, being a warm-season crop shows relatively better tolerance to high temperature during most of the growing period. However, when its reproductive period coincides with abnormally high temperature (> 40°C) during summer seasons, the impact of heat stress on mung bean is severe (Pratap *et al.*, 2019). In recent global warming scenarios, more frequent and unexpected episodes of extremely high temperatures (> 45°C) are being observed. The United Nations' Intergovernmental Panel on Climate Change (IPCC) in its sixth assessment report, Climate Change 2021 have stated that average surface temperature is expected to rise by 1.5°C in less than 20 years. At high temperatures, the formation of reactive oxygen species (ROS) destroys plants due to oxidative stress resulting in membrane damage. High temperature has been reported in many

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instances, to cause a reduction in CO_2 assimilation and photosynthetic system damage in plants. Under high-temperature stress, mung bean phenology is accelerated leading to a sizable reduction in leaf area, photosynthesis, biomass, flowers, pods and yield (Patriyawaty *et al.*, 2018). The application of some thermo-protectant compounds in the form of phytohormones (salicylic acids and abscisic acids etc), signalling molecules (GABA, polyamines, Ca^{2+} etc), osmoprotectants and certain nano-particles (selenium, silver etc.) (proline, glycine betaine, trehalose) have been reported highly beneficial for plants under high-temperature stress, as these molecules possess antioxidant and growth-promoting abilities (Akhtar *et al.*, 2015). Exogenous application of these thermo-protective molecules enhance heat tolerance and yield in mung bean. These thermo-protectants play a vital role in mitigating the harmful impacts of high-temperature by detoxifying ROS via the up-regulation of antioxidant mechanisms, osmotic adjustments, maintaining redox homeostasis and triggering better functioning of plants as depicted in Fig. 1.

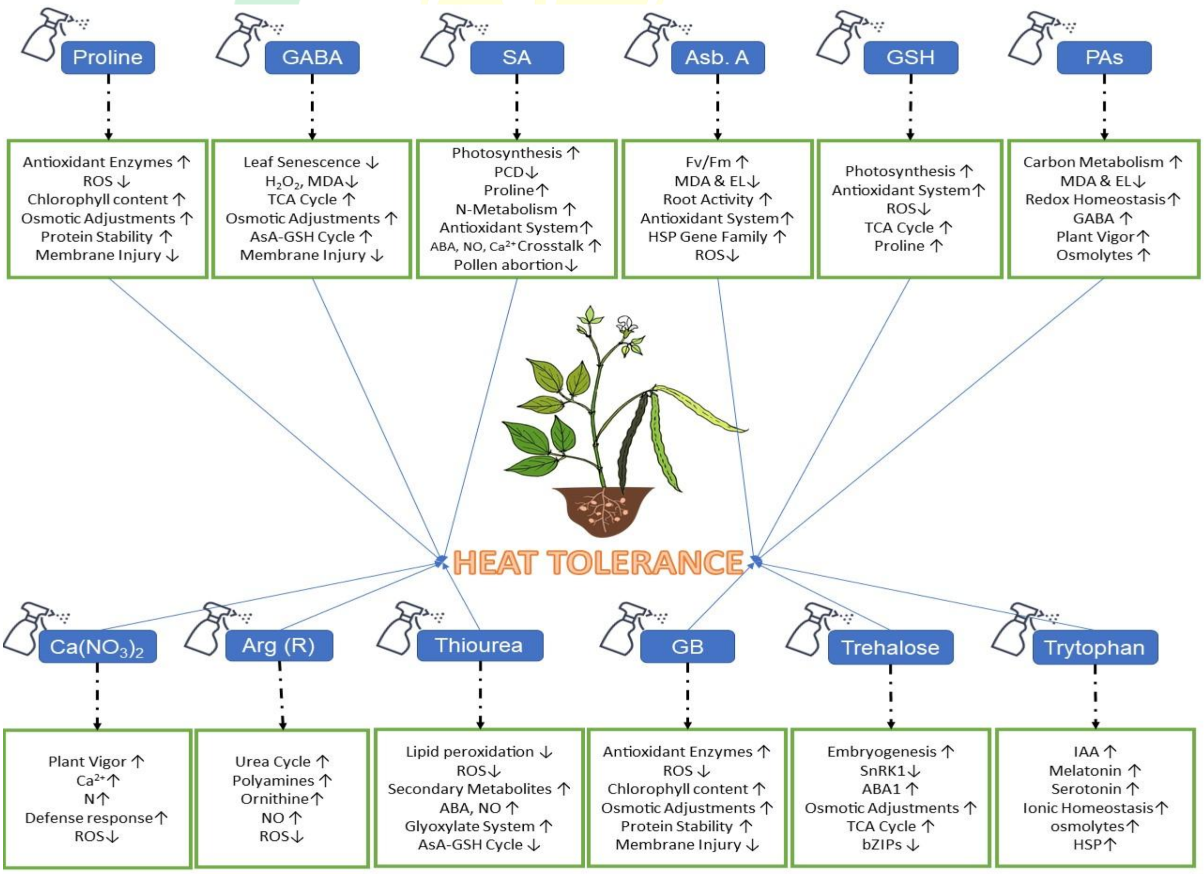

Fig 1. The role of some bioregulatory molecules reported improving heat tolerance in crop plants.

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Application of certain thermo-protectants molecules provides a protective shield to plants under high-temperature adverse conditions and the role of some important bioactive compounds as a thermo-protectant in mung bean, in brief, is as follows.

Role of some important bioactive compounds as a thermo-protectant

Phyto-hormones: Phytohormones play a promising role as a thermo-protectant and improve tolerance by acting as an osmolyte, detoxifying ROS by improving antioxidant capacity and modulating gene regulation. The notable effects of important plant growth regulators in mung bean are as follows.

Phytohormone	Dose	Improve tolerance/yield by	Reference
Salicylic Acid	69 ppm	Decreasing lipid peroxidation, increasing SOD activity, glutathione content and catalase activity	Saleh *et al.*, 2007
Gibberellic Acid	34.6 ppm	Increasing β-amylase activity, improving plant growth and defence	Mansoor and Naqvi, 2012

Osmolytes: Osmolytes like proline, glycine betaine and trehalose are accumulated under abiotic stresses including high temperature stress and these take part in a well-known adaptive mechanism of the plants for better survival. Since to date not a single heat tolerant variety of mung bean is available therefore, available heat-sensitive varieties cannot accumulate these molecules. In such varieties heat tolerance can be improved by the exogenous application of osmoprotectants.

Osmolyte	Dose	Improve tolerance/yield by	Reference
Proline	575 ppm	Increasing pollen fertility, stigma and ovule function via enhanced leaf water status, chlorophyll, carbon fixation and assimilation capacity	Priya *et al.*, 2019 b

Signalling Molecules: Various bioregulatory compounds like polyamines, non-protein amino acids, thiols, etc protect the plant under heat stress by maintaining the membrane integrity, stabilizing activities, and maintaining the structure of the protein, enzymes complexes and redox potential in stressed plants. Some important compounds and their role in providing thermal tolerance to mung bean are as follows.

Signalling Molecule	Dose	Improve tolerance/yield by	Reference
γ-aminobutyric acid	103.12 ppm	Improving leaf water status, the number of pods (28%) and seed weight (27%) per plant and less membrane damage	Priya *et al.*, 2019a
Glutathione	153.66 ppm	Improving antioxidant defence system and glyoxalase system	Nahar *et al.*, 2015
Spermine	40.47 ppm	Improving osmoregulation, antioxidant enzyme activity and glyoxalase system	Nahar *et al.*, 2017
Ascorbic Acid	8.80 ppm	Increasing Chlorophyll activity, leaf water status, ASC/GSH pathway	Kumar *et al.*, 2011

Similarly, exogenous applications of several other bioactive compounds (thiourea, calcium nitrate, tryptophan, etc) were reported to be credible to minimize the adverse effect of heat stress in various other crops, but their application as thermo-protectants are yet to be explored in mung bean under high-temperature stress. Thus, in the view of above facts, it is clear that thermo-protectants have the potential to protect mung bean from the harmful effects of high temperature and improve the thermotolerance and yield of mung bean crops under high-temperature stress conditions.

Conclusion

Global warming has emerged as one of the most pressing issues of this century. High-temperature stress negatively impacts various physiological and biochemical features associated with growth and development and determine reproductive success. To date, no heat-tolerant variety of mung bean is available therefore, exogenous application of thermo-protectant compounds is an effective option to manage mung bean crop survival for better yield and induced thermo-tolerance under heat stress conditions. Further studies pertaining to this direction are needed that can be utilized to make a more effective strategy for efficient high-temperature management in mung bean.

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