Editorial

Get Together: The Interaction between Melatonin and Salicylic Acid as a Strategy to Improve Plant Stress Tolerance

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Abstract: Both melatonin and salicylic acid (SA) have been demonstrated to play multiple functions in plant physiological processes and biotic and abiotic stress responses. So far, these regulatory molecules have been separately studied despite sharing a common biosynthetic precursor and their similar physiological actions and stress regulation signals. The review published in Agronomy by Hernández-Ruiz and Arnao entitled “Relationship of melatonin and salicylic acid in biotic/abiotic stress responses” highlights the coincidences and similarities of both regulatory molecules via a thorough literature search and proposes an action model for their interaction in plant stress responses. Despite the undeniable interest and potential impact of this view, it has been focused only on coincident regulatory aspects of SA and melatonin, and the antioxidant-mediated model of interaction that has been proposed is rather speculative and needs to be mechanistically demonstrated. Nevertheless, the mentioned review leads to future research on the melatonin-SA crosstalk to improve biotic and abiotic stress tolerance, which is of utmost importance to ensure food production in the actual age of pandemics and for the upcoming climate crisis scenario.

Keywords: melatonin; salicylic acid; abiotic stress; biotic stress; antioxidative metabolism; food sustainability

The average farm productivity must reach 70–80% of the yield potential to meet future food demands, while the actual yield does not reach 50% of the potential capacity for most crops and agricultural areas. Out of the total food production capacity worldwide, the biotic stresses account for more than 30% of yield loss, with an additional 20–30% due to abiotic stress factors [1]. This situation is likely to worsen as climatic conditions become more extreme due to global warming, resulting in more frequent and severe droughts and extreme temperatures leading to increased soil degradation and nutrient leaching. This is why deepening our knowledge of stress responses of crop plants is crucial to ensure and sustain future food production.

Huge efforts have been made during the last 50 years to improve the stress tolerance in plants, but with limited success due in part to insufficient knowledge about the stress-responsive mechanisms involved in limiting plant growth and yield. Considering that surviving and/or yielding under stress conditions imply big costs (for defence against pathogen attack, intracellular compartmentation and excretion, synthesis of organic solutes for osmotic adjustment and protein turnover, etc.), all the processes implicated in plant signalling are then of great importance in the response to stress. During the last few years, several studies have appeared proving that hormone signalling plays a critical role in regulating plant stress responses. In fact, these hormonal signals not only regulate the adaptive responses but also affect the normal growth of the harvestable organs and thus influence economic productivity. Pioneer studies on attempting hormonal changes under abiotic stress (apart from the classical ABA) demonstrated the existence of a complex hormonal network [2–4]. Biotic stress responses
have also been profoundly studied concerning the variations in the hormonal balance, especially of jasmonic acid (JA) and salicylic acid (SA) [5]. Furthermore, other metabolites or signalling molecules, such as melatonin, have been considered for a long time to play an important role in the plant responses to biotic and abiotic stress factors [6]. In fact, the recent identification of the first plant melatonin receptor has opened the door to this regulatory molecule being considered a new plant hormone. However, due to the diversity of its actions, melatonin has also been proposed as a plant master regulator [7,8].

It is more than plausible that there is a cross-talk not only among different hormone classes but also between hormones and other signalling molecules implicated in plant physiological responses and stress tolerance, although the molecular mechanisms by which this occurs are still not clear. In this regard, a review addressing the interaction between SA and the pleiotropic molecule melatonin in the plant stress responses have been published in Agronomy [9]. It is rewarding to read this review, highlighting the similarities between SA and melatonin, as signalling molecules, which proposes an integrated functioning model of their implication in the regulation of biotic and abiotic stresses. Following an important literature search, the authors first concisely summarize the sharing points of the biosynthetic pathways of both molecules, which have a common precursor, the chorismic acid, as well as the three aromatic amino acids involved, phenylalanine, tryptophan, and tyrosine. Furthermore, the article describes the common physiological effects of SA and melatonin, and makes a thorough compilation of studies addressing (separately) the effect of melatonin and SA in abiotic and biotic stress responses. However, the authors missed the opportunity to reflect that only casual or indirect pieces of evidence of the interaction of these two regulatory molecules have been obtained so far, and thus proposing a consistent action model will require profound research on the molecular mechanisms underlying such interaction.

The review by Hernández-Ruiz and Arnao [9] suggests the implication of the antioxidative metabolism in the plant stress response mediated by melatonin, with NO playing a central role, and SA also implicated by a downstream signalling pathway and crosstalk with other hormones. Although plausible, the proposed action model is a bit “adventurous”, and it should be regarded carefully. In fact, within the proposed model, melatonin is the key player, directly or indirectly enhancing, not only SA but also JA and ethylene, which finally active pathogen defence responses. Another important aspect that was not satisfactorily considered in the review is the mechanistic relationship between melatonin and SA in the abiotic stress response.

As future prospects, the authors propose to deepen the study of the crosstalk with other hormones and generate SA- and melatonin-overexpressing plants. While the interest of such studies is unquestionable, the research on the molecular mechanism underlying the interaction between SA and melatonin should rather be prioritized by: (1) transcriptomic and gene expression analyses, (2) knock-out and knock-down SA and melatonin single and double mutants, and (3) overexpressing SA and melatonin biosynthetic genes. Nonetheless, the interest of the review is not in doubt since it brings together many common aspects of SA and melatonin as pleiotropic molecules with a wide range of functions in the plants. Importantly, the focus has been given to the role of these two regulatory compounds in biotic and abiotic stress responses, which opens new perspectives for their use in future breeding programs of stress tolerance.

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References

1. FAO; DWFI. *Yield Gap Analysis of Field Crops–Methods and Case Studies*; FAO Water Reports No. 41; Sadras, V.O., Cassman, K.G.G., Grassini, P., Hall, A.J., Bastiaanssen, W.G.M., Laborte, A.G., Milne, A.E., Sileshi, G., Steduto, P., Eds.; FAO: Rome, Italy, 2015.

2. Albacete, A.; Ghanem, M.E.; Martínez-Andújar, C.; Acosta, M.; Sánchez-Bravo, J.; Martinez, V.; Lutts, S.; Dodd, I.C.; Pérez-Alfocea, F. Hormonal changes in relation to biomass partitioning and shoot growth impairment in salinized tomato (Solanum lycopersicum L.) plants. *J. Exp. Bot.* 2008, 59, 4119–4131. [CrossRef] [PubMed]

3. Ghanem, M.E.; Albacete, A.; Martínez-Andújar, C.; Acosta, M.; Romero-Aranda, R.; Dodd, I.C.; Lutts, S.; Pérez-Alfocea, F. Hormonal changes during salinity-induced leaf senescence in tomato (Solanum lycopersicum L.). *J. Exp. Bot.* 2008, 59, 3039–3050. [CrossRef] [PubMed]

4. Albacete, A.; Martínez-Andújar, C.; Ghanem, M.E.; Acosta, M.; Sánchez-Bravo, J.; Asins, M.J.; Cuartero, J.; Lutts, S.; Doss, I.C.; Pérez-Alfocea, F. Rootstock-mediated changes in xylem ionic and hormonal status are correlated with delayed leaf senescence, and increased leaf area and crop productivity in salinized tomato. *Plant. Cell Environ.* 2009, 32, 928–938. [CrossRef] [PubMed]

5. Liu, L.; Sonbol, F.-M.; Huot, B.; Gu, Y.; Withers, J.; Mwimba, M.; Yao, J.; He, S.Y.; Dong, X. Salicylic acid receptors activate jasmonic acid signalling through a non-canonical pathway to promote effector-triggered immunity. *Nat. Commun.* 2016, 7, 13099. [CrossRef] [PubMed]

6. Arnao, M.B.; Hernández-Ruiz, J. Melatonin: Plant growth regulator and/or biostimulator during stress? *Trends Plant Sci.* 2014, 19, 789–797. [CrossRef] [PubMed]

7. Arnao, M.B.; Hernández-Ruiz, J. Melatonin: A New Plant Hormone and/or a Plant Master Regulator? *Trends Plant Sci.* 2019, 24, 38–48. [CrossRef] [PubMed]

8. Arnao, M.B.; Hernández-Ruiz, J. Is phytomelatonin a new plant hormone? *Agronomy* 2020, 10, 95. [CrossRef]

9. Hernández-Ruiz, J.; Arnao, M.B. Relationship of melatonin and salicylic acid in Biotic/Abiotic plant stress responses. *Agronomy* 2018, 8, 33. [CrossRef]

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