MANAGING PLANT STRESS USING SALICYLIC ACID: PHYSIOLOGICAL AND MOLECULAR ASPECTS

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Preface

Plants, during their life, encounter various challenges, and one of the main threats for their normal development is abiotic stress. The major abiotic stresses possessing threat to plants are water scarcity, salinity, extreme temperatures, heavy metals, and pesticides. All these abiotic factors can cause phytotoxicity, either directly or indirectly, resulting in interruption to plant’s growth and development which eventually decrease plant yield. Researchers all over the world have already specified abiotic stresses as the main danger for agrarian systems. However, plant’s internal defense system tries to counterattack the negative impacts of abiotic stresses by regulating their biological processes. But, above a threshold level of a particular stress, even plant’s internal antioxidative defense system is unable to entirely protect plants from the deleterious effects of abiotic stress. So, plants need some external stimulus or support to boost the level of defense system to survive under challenging environments. Exogenous application of plant hormones is one of the best and eco-friendly approaches to trigger the defense system of stressed plants.

In the recent past, a lot of investigations have been focused on studying the mechanisms of plant hormone-mediated regulation of plant growth and development under abiotic stress conditions. Salicylic acid is an important plant hormone which acts a multifunctional molecule and regulates key physiological and biochemical processes in plants. This hormone also provides resistance to plants against abiotic stresses by regulating key cell signaling pathways. Exogenous application of SA helps in convalescing the growth and development of stressed plants by reducing the oxidative stress accompanied by enhanced performance of antioxidative defense machinery. At present, scientists all over the world are very keen to study the deep mechanisms of SA-modulated abiotic stress responses by using various advanced molecular techniques. These advancements in research approach can be beneficial in exploring some important genetic pathways which can be applied to develop abiotic stress-tolerant plant varieties. So, recently, many studies have been carried out to find the deep molecular mechanisms explaining SA-mediated regulation of plant growth under abiotic stress. So, our purpose is to compile all the latest developments described in the arena of SA-mediated regulation of abiotic stress.

The first chapter explains the general roles of salicylic acid in plant biology. Chapter 2 discusses the role of salicylic acid in plants during stressful conditions in relation to omics approaches. Chapter 3 focuses on describing the possible role of salicylic acid in regulation of primary metabolisms like respiration and photosynthesis in plants growing under challenging conditions. The next chapter discusses salicylic acid-mediated secondary metabolism in plants under abiotic stress. Further chapters explore the role of salicylic acid in stressed plants by important aspects like mineral nutrition, seed germination to fruit maturation. Chapter 7 brings the updated knowledge about the role of salicylic acid in the postharvest technology. The next chapters focus on exploring salicylic acid-mediated physiological and molecular mechanism in plants under stresses like metal(loid), heat, chilling, and drought. Chapter 14 describes in detail the regulation of photosynthesis by salicylic acid under optimal and suboptimal conditions. Further chapters focus on describing the roles of salicylic acid in mediating stress conditions in plants at genetic levels including the phytohormonal cross talk and post-transnational modifications.

This book is a collection of recent developments in the field of salicylic acid biology in relation to challenging environment conditions. To the academic and industry sectors, the book provides useful hints for the development of eco-friendly stress-mediating approaches as well as helps to understand the future importance and involvement of salicylic acid in safe food production. Therefore, we believe that this book will be a vital source of information for scientists and academics working in the field of abiotic stress tolerance.

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1
Salicylic Acid: A Regulator of Plant Growth and Development

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Introduction

In plants, the phytohormones act as endogenous signals, both spatially and temporally, regulating a number of physiological functions. The cross talk between various phytohormones helps the plant to withstand biotic and abiotic stresses. This cross talk of plant hormones has evolved into a complex network within the plants, thus helping the plants having a balanced reaction to developmental and environmental stimuli (Sharma et al. 2018, 2019a; Koo et al. 2020). Salicylic acid (SA) or ortho-hydroxybenzoic acid is a member of the group of plant phenolics with a seven-carbon (C) skeleton. A study of reproductive structures and leaves of 34 plant species confirmed that SA is ubiquitously distributed in plant kingdom (Raskin et al. 1990). The name SA is from Salix (Latin word) as it was found to be an active constituent of willow tree bark (*Salix* sp.) which was used extensively to cure fever and aches (Khan et al. 2015).

The biosynthesis of SA in plants involves the isochorismate synthase (ICS) pathway and phenylalanine ammonia-lyase (PAL) pathway (Janda et al. 2014). The ICS pathway was first discovered in *Pseudomonas* species and the *PmsCEAB* gene cluster was found to play the key role in the synthesis of SA. The conversion of chorismate to isochorismate (IC) is catalyzed by *PmsC* gene and then isochorismate pyruvatelyase encoded by the *PmsB* gene converts IC to SA making SA synthesis from chorismate a two-step process (Mercado-Blanco et al. 2001; Lefevere et al. 2020). In the PAL pathway, the key enzyme is chorismate mutase (CM) which catalyzes the process of converting CM to prephenate. Prephenate gets converted to phenylalanine (Phe), which in turn is converted to trans-cinnamic acid (tCA) by the enzyme PAL. The next step involves the catalyzing of the conversion of tCA to benzoic acid (BA) by abnormal inflorescence meristem1 (AIM1), which is a multifunctional protein (MFP) family member (Rylott et al. 2006; Arent et al. 2010). The last step in the PAL pathway is the conversion of BA to SA which is presumed to be catalyzed by benzoic acid hydroxylase (Lefevere et al. 2020).

The ICS as well as PAL pathways to synthesize SA start from chorismate, and the importance of both ICS and PAL varies in different species of plants, as not all enzymes which catalyze various reactions in these pathways have been found in all plants. The ICS pathway plays an important role in SA biosynthesis in *Arabidopsis*, and PAL has been found to be more important in rice, while in soybeans, both pathways contribute equally (Silverman et al. 1995; Duan et al. 2014).

In plants, SA plays a significant part in the growth, development, and in the protection from biotic and abiotic stresses (Khan et al. 2015; Sharma et al. 2019b, 2020; Prakash et al. 2021) (Figure 1.1). The role of SA in defense mechanisms of plant was established during the last 30 years and before that it was recognized as an unimportant secondary plant metabolite. Since 1979, when White (1979) reported the role of SA in tobacco plants' disease resistance, numerous findings showed the role of SA as an important regulatory substance in plants (Chen et al. 2009). Studies have shown that in plants, SA plays a vital part in disease resistance, DNA damage/repair, seed germination, fruit yield, and thermogenesis (Dempsey and Klessig 2017). Increased levels of SA are seen in the presence of an infection, and if supplied exogenously, SA strengthens the plant defense system (Lefevere et al. 2020). In this review, we have focused on the role of SA in plants as a regulator of growth and development and providing resistance against various stresses.

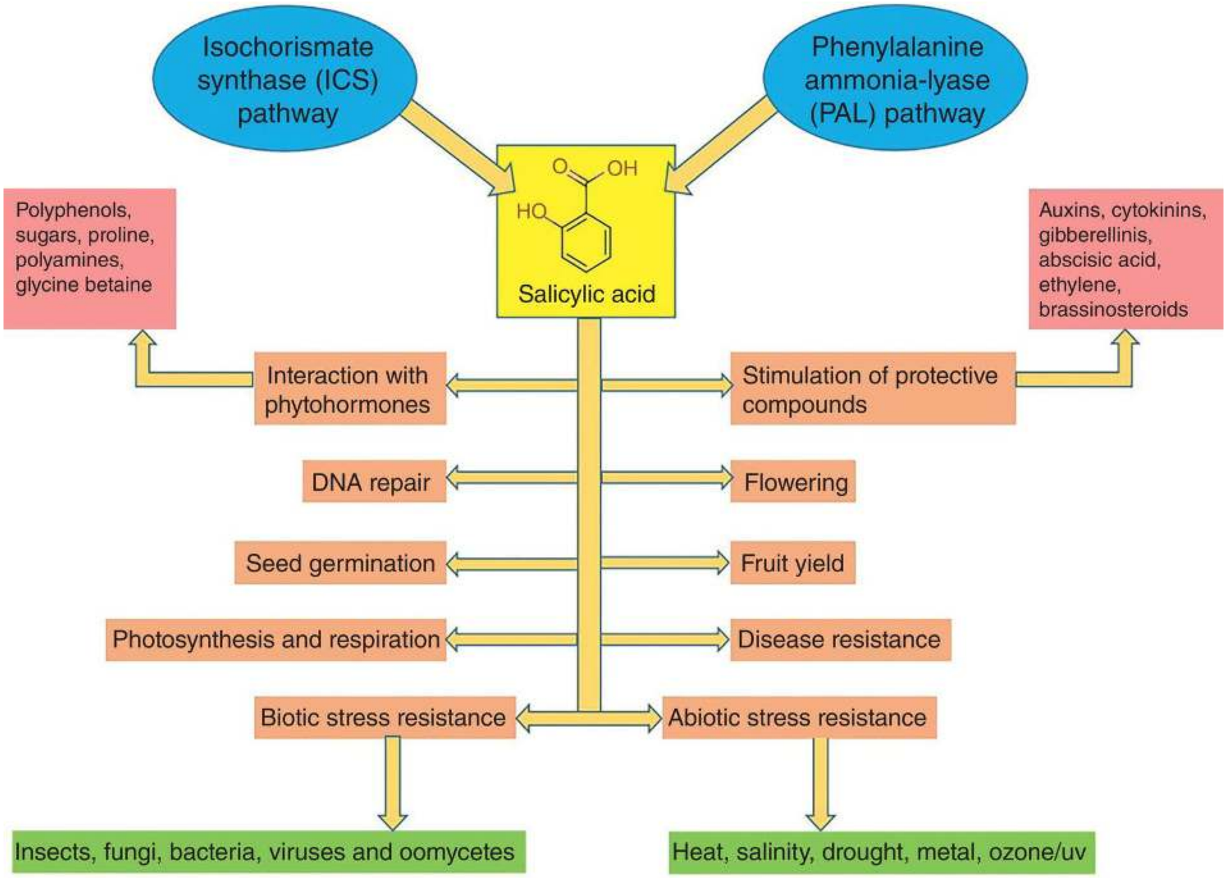

Figure 1.1 Schematization of the role of salicylic acid in plants.

Source: Based on Khan et al. 2015; Sharma et al. 2019b, Sharma et al. 2020; Prakash et al. 2021.

Salicylic Acid and Plant Growth

SA plays an important role in plant growth, along with other phytohormones, and its effects on growth, when applied exogenously, is affected by the species of the plant and its stage of development as well as its concentration (Vicente and Plasencia 2011). It has been reported that more than 1 mM of SA is considered a high concentration and has negative effects (Koo et al. 2020). Barley and maize seeds did not show any germination when imbibed in >3 mM of SA (Guan and Scandalios 1995; Xie et al. 2007). On the contrary, when maize seeds were imbibed in ~0.3 mM–