Cross talk signalling: an emerging defense strategy in plants

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Important suites of plant responses to foreign attack are mediated by plant hormones such as jasmonate, salicylate, abscisic acid and brassinosteroids, which independently provide resistance to herbivorous insects, pathogens and other environmental challenges. This biochemical link of general plant defense strategies is regulated by both positive and negative interaction between phytohormones. Here we consider the mechanistic perspective of plants against pathogens, insects and osmotic adaptations. ABA-JA and salicylic acid mediated signalling pathways provide possible responses to biotic and abiotic stresses in plants. Phytohormonal ecology is attempting to link organisms and stress factors to develop a predictive framework for how and why plants coordinate with the environment.

Plants must protect themselves against various biotic and abiotic stresses that damage their tissues in many ways. Hormone signalling is integrated at several levels during plant growth and development[1]. Cross talks between hormonal and defense signalling pathways should reveal new potential targets for the development of host resistance mechanisms and phytohormones[2,3]. Jasmonate controls defense gene expression, growth and fertility in *Arabidopsis thaliana* through conjugation with amino acids such as isoleucine to form the active hormone jasmonoyl-isoleucine (JA-Ile), a major biologically active jasmonate[4,5]. Whereas salicylic acid is synthesized by plants in response to a diverse range of biotic and abiotic factor to establish the resistance mechanisms[6,7]. Phytohormonal interactions are specific and depend on the type of attack such as a physical wound created by insects feeding may facilitate the entry of opportunistic pathogens. Conversely some insects like aphids and thrips prefer the yellow colour of diseased plants. Attack by one organism may be positively associated with attack by other organisms. Plants should utilize strong defense systems that are either effective against both type of attackers or develop a resistance against them[8,9]. Similarly, cross talk in cold, draught and salt stress signalling components might be organized into a network action[10,11]. This complexity of signalling makes the answer to the question how cross talk signalling pathways are regulated in response to biotic and abiotic stresses. Ecological significance of signal interactions in plant defense system depends on the specific metabolic defensive compounds.

A major goal of phytohormonal ecology is to understand the role of plant hormones in determining plant responses to various environmental challenges. This includes the strategy that each hormone plays in response to individual stress as well as the coordination of multiple hormones in response to multiple stresses. However, complex defense signalling network in nature should join forces to place molecular mechanism of induced plant defenses in an ecological perspective. One particular challenge is to unite the knowledge of phytohormonal biochemistry with the patterns of ecological correlation among stresses. One possible strategy to understand the interaction between stresses is hormonal and biochemical signalling which may influence the severity or the ability of plants to adapt against various stresses[12]. Current biochemical and molecular models of phytohormonal signalling pathways as predominantly responsible for plant resistance to adverse environmental conditions may be utilized for the genetic identification of signalling components in plants.

Phytohormones interact together for defense signal networking to fine tune defense. Salicylic acid (SA), JA, abscisic acid (ABA) are recognized as key players in the regulation of the signalling pathway[13]. The primary immune response has evolved to recognize common features of organisms that interact with the plant and to translate this recognition into a defense response that is especially directed against the attack encounter[14]. But complete cross talk signalling pathways and their receptors require to be elucidated.

Patterns and correlation between plant stresses

Phytohormonal responses to one stress influences its responses to other stresses. This may be due to plant water status, which plays a major role in the movement, germination and leaf entry of many pathogens[9,14]. Availability of water may also affect osmoticum balance and is associated with the change in the microenvironment (temperature and humidity). The logic of this argument is that stressed plants invest less in defense and may be of higher nutritional value. This hypothesis was tested in a meta-analysis of various experiments that manipulated abiotic stress and the results showed support for the plant stress hypothesis. There is also evidence for an ecological association between moisture and herbivory[15]. Plants respond to natural damage and induction by elicitors in a dose-dependent manner and develop biochemical link through signalling mechanisms. Signalling interactions between phytohormonal pathways were detected through either antagonistic or synergistic activity of phytohormones[1]. For example JA singly induced polyphenol oxidase (PPO) whereas synthetic salicylate (BTH) had no effect on PPO and there was reduced PPO activity in dual elicited plants compared to plants elicited with JA alone[9]. These ecological correlations among stresses can be used as a framework to examine phytohormonal interactions that regulate plant responses to the respective stresses.

Signalling interactions between phytohormones

Biochemical signalling interactions between phytohormones are known to have strong influence on the metabolic profile of plants in response to various environmental stresses. When plants experience stress, activation of highly phytogenetically conserved phytohormonal pathways

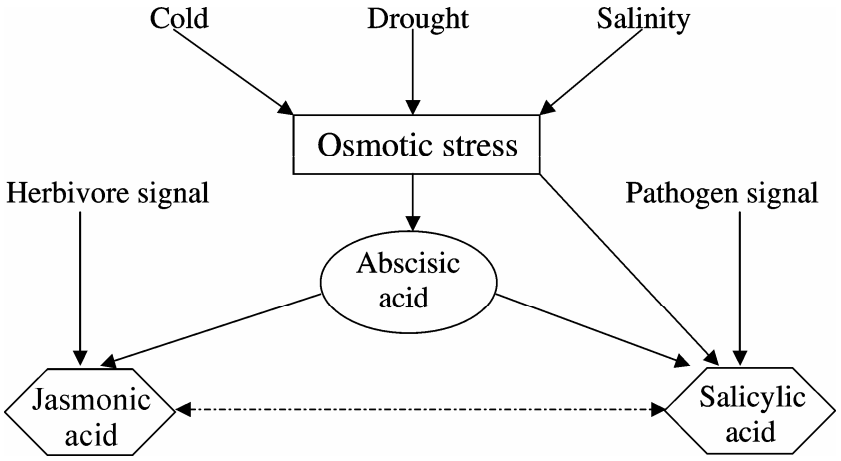

Figure 1. Proposed model to show a relationship among ABA–JA–SA signalling pathways in plants in response to biotic and abiotic stresses.

are thought to mediate adoptive responses. Current biochemical and molecular signalling approved the involvement of phytohormones and their predominant role for plant resistance to biotic and abiotic stresses[1,4]. These lines of action have also been supported by microassay to analyse expression of many ABA–JA and SA regulated genes, emphasizing the coordination responses mediated by these hormones. Recently, it was reported that exogenous SA interfered with various physiological processes[16]. Thus, complex interactions occur among ABA, JA and SA phytohormones that are important regulators of biotic and abiotic stress responses in plants which are biochemically linked[17] (Figure 1).

There are several ways in which the phytohormonal pathways are known to interact and regulate the growth and development of plants[4,14,18]. Interaction between phytohormonal mediated signalling pathways depends on contraction and timing of elicitation or nature of stresses[11]. Jasmonate and salicylate pathways are two of the key biochemical response mechanisms that can be triggered by various biotic and abiotic stresses, and function as necessary signalling molecules responsible for defensive responses in plants. Recent studies suggested that SA-dependent inhibition of JA action could be manifested via activation of non-repressor of pathogenesis-related genes (NPRI)[19].

Survival strategies of plants under adverse environmental conditions induced after cross talk among various hormonal signalling pathways may lead to the development of new hypotheses. Study of the evolution of hormone pathways will provide insights into how these pathways have adapted to regulate complex and diverse developmental processes.

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ACKNOWLEDGEMENT. We thank Dr A. K. Singh, Head, Department of Botany, Udai Pratap Autonomous College, M.G. Kashi Vidyapeeth University, Varanasi, for providing facilities.

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