Natural resistance of plants against pathogens – A mini review

Safa RGUEZ¹, Ilhem BARBOURA², Majdi HAMMAMI¹*, Ibtissem HAMROUNI SELLEMI¹

¹ Laboratoire de Medicinal and Aromatic Plants, Centre of Biotechnology of Borj Cedria, BP 901, 2050, Hammam-Lif, Tunisia.
² Laboratoire de biochimie, CHU Farhat Hached-Sousse, Tunisie.

ARTICLE INFO
Received January 6th, 2022
Received in revised form May 30th, 2022
Accepted June 1st, 2022

Keywords:
Biotic stress,
Plant defence,
Elicitor,
Natural product.

ABSTRACT
To control pathogen attack, plant’s defense system relies on performed and induced responses. The induced responses were activated after pathogen attack. Successive signal transmission and cellular reactions aimed to eliminate the pathogen. This review covered the different plant pathways to defend against microbial attack, mainly, the recognition of the pathogen, the cellular responses, the intercellular signaling post and pre-infection. Further, this paper resumes the defense compounds and defense mechanism of infected plants.

1. Introduction:
Plants protect themselves during their development against pathogens by using a complex defense system that involves constitutive and induced defenses following their interactions with different pathogens [1]. The preformed or constitutive defenses can thus be localized at the level of different parts of the plant and are constituted by physical barriers such as the bark and epidermis and chemical barriers such as toxins [2]. Unlike constitutive defenses, induced defenses can develop as a result of the interaction between the plant and the pathogen [1]. In this context, the present review summarizes the main defense ways of the plant cell against different types of aggression. Specifically, pathogen identification, cellular responses, and intercellular communication after and pre-infection. This paper also recaps the defensive chemicals and defense mechanisms of diseased plants.

2. Recognition of the pathogen:
When a plant is attacked by a pathogen, plant / pathogen recognition can take place and involves a system called: gene for gene. This system involves a so-called avirulence (Avr) gene in the pathogen and a so-called resistance (R) gene in the plant. As for the course of the interaction, there is the presence of the corresponding Avr gene, the interaction is compatible. The pathogen is then unable to induce the disease and the plant is resistant. Otherwise, the interaction is incompatible, the plant is said to be sensitive and there is disease [3]. The recognition of the pathogen by the plant can also be effected by the plant's perception of molecules called elicitors or PAMPs "Pathogen-Associated Molecular Pattern” or PAMMs "Microbial-Associated Molecular Pattern" [1]. The elicitors can be secreted by the pathogen, in this case, they are qualified as exogenous as they can also be produced by the plant and in this case, they are qualified as endogenous elicitors. The nature of the elicitors is very varied and the most abundant are oligosaccharides, lipids, polypeptides and glycoproteins [4-5] (Figure 1).
Figure 1. Pathogen recognition: Gene-For-Gene Concept.

3. Cellular responses:
When the plant recognizes the pathogen, rapid signal transduction reactions take place in the attacked cells. These reactions occur first at the intracellular level and second at the extracellular level [6-7]. After infection by the pathogen, changes in the permeability of the plasma membrane are put in place and often result in membrane depolarization associated with ion flows (influx of Ca$^{2+}$ and efflux of K$^+$), activations of protein kinases and phosphatases and by production of reactive oxygen species (ROS), nitric oxide as well as lipid oxidation. ROS are represented by the superoxide anion (O$_2^-$), hydrogen peroxide (H$_2$O$_2$), the hydroperoxyl group and the hydroxyl group. These compounds can be the source of other defense reactions in the plant. Thus, ROS are involved in the strengthening of the cell wall, the establishment of the hypersensitive response and contribute to the expression of defense genes [8]. Nitric oxide (NO) is a signaling molecule used by plants and is involved in the plant / pathogen interaction by activating defense genes [9]. In fact, during attack by a pathogen, NO accumulates in the plant and it can play several roles, in particular its toxicity to microorganisms and its involvement in signaling cascades which contributes to the strengthening of the cell wall and even the induction of defense gene expression [10].

4. Intercellular signalling:
Five types of molecules are involved in cell signaling: jasmonic acid, salicylic acid, ethylene, systemine and abscisic acid [7]. These molecules are involved in the intercellular transduction of the signal in order to induce resistance near and far from the site of infection, which allows different parts of the plant to be informed of the external aggression caused. These signal molecules are involved in various defense mechanisms and are even characteristic of certain resistance phenomena (Figure 2).

5. Defense compounds:
Following infection of the plant with a pathogen, various defense compounds can be synthesized. PR or "Pathogenesis-Related" proteins can be produced by the plant when interacting with a pathogen. Seventeen families of PR proteins with different activities such as the degradation of the fungal wall have been identified [11]. In addition to these PR proteins, other defense molecules are synthesized during plant infection with the pathogen, such as the polygalacturon inhibitor proteins.

6. Defense mechanisms:
6.1. Hypersensitive or HR response:
The hypersensitivity reaction (RH) is one of the most effective defense responses in plants. It is characterized by rapid and local death of cells which are in direct contact with the pathogen, and this phenomenon manifests itself phenotypically by the appearance of necrotic lesions localized at the site of penetration of the pathogen. This HR-associated cell death has characteristics of programmed cell death (PCD) [12].
6.2. Acquired local resistance RLA:
Local acquired resistance or RLA is the result of plant induction by cells in a state of cell death by transmission of signal molecules such as salicylic acid, ethylene and jasmonic acid. This is because the hypersensitivity reaction zone is characterized by the accumulation of antimicrobial molecules such as phenolic compounds. Resistance is strong in this area, which contributes to inhibiting the progression of the pathogen [13].

6.3. Acquired systemic resistance RSA:
As a result of the plant’s interaction with a pathogen, a systemic resistance consisting of a defense mechanism is activated in the plant. This resistance gives the plant lasting resistance against pathogenic infections. There are two mechanisms of systemic resistance: The first is the acquired systemic resistance (RSA) which is induced following the interaction of the plant with a virulent microorganisms [14]. The second is Induced Systemic Resistance (RSI) which is activated as a result of the interaction of the plant and beneficial bacteria [3]. RSA is manifested by the activation of a number of genes allowing the induction and maintenance of whole plant resistance against several pathogens. RSA is also dependent on the accumulation of salicylic acid locally and systemically [15] (Figure 3).
6.4. Methods of combating fungal diseases:
Tomato crops in Tunisia are often affected by several diseases caused by pathogenic microorganisms such as fungi, bacteria and viruses [16]. Gray rot caused by *B. cinerea* is one of the most prevalent diseases in the world, it infects leaves, stems and fruits causing severe defoliation, flower death and stem lesions which lead to the death of plants and rotting of harvested tomatoes [17]. This fungal disease causes severe losses in tomato plants grown in open fields and in greenhouses, causing the premature death of 70% of tomato plants and consequently reducing yields according to O’neill, et al. (1997) [18]. Indeed, the lack of adequate disease resistance in current plant varieties implies the development and use of systemic fungicides.

6.5. Chemical control:
The control of plant diseases such as gray mold has been largely achieved through the use of chemical pesticides. In general, a wide variety of chemical fungicides control plant diseases by inhibiting growth or killing pathogens [19]. Despite their usefulness in agricultural practices to increase productivity, pesticides can cause potential risks to the safety of food, the environment and all living things. Indeed, the emergence of fungicides leads to the loss of the efficacy of these compounds, to the development of fungal resistance, to residues in the fruits and to the problems of intoxication of the applicators [20].

6.6. Biological control:
Today, scientists need to focus on developing new alternatives that are more effective than chemical pesticides for major crops. The biological control of plant diseases by microorganisms and bioactive products including EOs or their active substances is considered to be a more natural and more acceptable alternative to chemical treatment methods [21]. According to several works, EOs from aromatic and medicinal plants have been shown to exert biological activity against fungi in vitro and in vivo and can be used as biofungicial products [22-25]. On the other hand, many treatments of plants with EOs have shown significant inhibitory effects on fungal growth including gray rot caused by *B. cinerea* [26]. For example, the in vivo application of EO of anmii (*Carum copticum*) and anise (*Pimpinella anisum*) at different concentrations could completely inhibit the mycelial growth of *B. cinerea* from tomato [27].

7. Conclusion:
Plants are regularly subjected to attacks from pathogens and set up their own defenses. Local defenses are put in place locally, at the level of the attacked cell: physical and/or chemical defenses. A few hours to a few days after the attack by the pathogen, a signal is sent. It will stimulate the natural defenses of the whole plant systemically and thus allow it to resist future attacks.

References:

© JASAB 2022