Review of innate and specific immunity in plants and animals

Marcello Iriti · Franco Faoro

Received: 19 March 2007 / Accepted: 9 May 2007 / Published online: 7 June 2007
© Springer Science+Business Media B.V. 2007

Abstract Innate immunity represents a trait common to plants and animals, based on the recognition of pathogen associated molecular patterns (PAMPs) by the host pattern recognition receptors (PRRs). It is generally assumed that a pathogen strain, or race, may have elaborated mechanisms to suppress, or evade, the PAMP-triggered immunity. Once this plan was successful, the colonization would have been counteracted by an adaptive strategy that a plant cultivar must have evolved as a second line of defence. In this co-evolutionary context, adaptive immunity and host resistance (cultivar-pathogen race/strain-specific) has been differently selected, in animals and plants respectively, to face specialized pathogens. Notwithstanding, plant host resistance, based on matching between resistance (R) and avirulence (avr) genes, represents a form of innate immunity, being R proteins similar to PRRs, although able to recognize specific virulence factors (avr proteins) rather than PAMPs. Besides, despite the lack of adaptive immunity preserved plants from autoimmune disorders, inappropriate plant immune responses may occur, producing some side-effects, in terms of fitness costs of induced resistance and autotoxicity. A set of similar defence responses shared from plants and animals, such as defensins, reactive oxygen species (ROS), oxylipins and programmed cell death (PCD) are briefly described.

Keywords Adaptive immunity · Autoimmunity · Autotoxicity · Fitness costs · innate immunity · SAR

Introduction

Either plants and animals are capable of recognizing and distinguishing between self and non-self. However, some phylogenetically ancient structures and strategies used in defence have been retained by parallel evolution, while some others appeared more recently during phylogensis [1, 2].

In this context, innate immunity, common to plants and animals, deeply differs from the adaptive one, which is restricted to vertebrates. Plants, lacking immunoglobulin molecules, circulating immune cells and phagocytic processes, do not possess any adaptive immunity, despite an array of innate defence mechanisms. Innate immunity can be considered as a battery of first-line defences against microbes, that pre-exists pathogen challenging and adaptive immunity triggering in animals [3].

Recognition of PAMPs (pathogen associated molecular patterns) represents the major trait of innate immunity common to plants and animals,
with the paradigm of drosophila toll receptors, mammalian TLRs (toll-like receptors) and the products of R (resistance) genes in plants, collectively termed as pattern recognition receptors (PRRs) [4]. Thus, PAMPs, more commonly known as general elicitors in plants, including lipopolysaccharides (LPS), peptidoglycans, flagellin, microbial cell wall fragments, phospholipids, proteins, double stranded RNA and methylated DNA, are able to elicit a host defence response by binding to receptors [5]. Besides, innate immunity receptors, both in plants and animals, are nonclonal and encoded in the germline, unlike B and T lymphocyte receptors, which are otherwise clonal and rearranged during development following somatic recombinations, in addition to be responsible for immunologic memory [6].

Perhaps, in this scenario, plants avoid the main harmful side effect of adaptive immunity, that is autoimmunity, due to abnormalities in self tolerance and the subsequent immune response to self antigens, though plant fitness costs, particularly in conditions of low pathogen pressure, might be somewhat identified with a sort of autoimmune disease [7].

The host-pathogen interaction

In animals, fungi causing mycoses consist of two classes. The primary pathogens infect healthy non-compromised individuals, whereas the opportunistic fungi cause disease in immunodeficient patients, as those receiving immunosuppressive therapy, undergoing bone marrow or solid organ transplantation or with acquired immunodeficiency syndrome (AIDS) [8, 9]. In plants, fungal pathogens can be divided into obligate and nonobligate parasites. The former, also known as biotrophs, can growth, develop and multiply only in close association with their living host, during their entire life cycle, while the latter can live on either living and dead hosts and nutrient media, requiring the plant only for a part of their life cycle. In addition, nonobligate parasites include facultative saprophytes or facultative parasites (or necrotrophs), depending on their main habitus, parasitic or saprophytic respectively [10].

With regard to infection process, two different routes exist in animals. The endogenous infection route pertains to the commensal body flora, depending on overgrowth of fungal strains (i.e. Candida albicans, Fig. 1a), at the nonsterile sites where they perform their commensalisms, such as stomatognathic system, digestive and respiratory tract and genital organs, or following translocation from these sites towards body compartments that react to their presence. Differently, the exogenous infection route is due to the entry of saprobes from the environment to the human body, usually through the airways and pulmonary tree [8, 11]. Plant pathogenic fungi show a rather similar behaviour, invading their hosts after entering through epigeous organs (leaves and stem), such as rust fungi (Fig. 1b) and downy mildews, or hypogeous organs (roots), for instance Rhizoctonia solani [10]. However, a downright endogenous infection route does not exist, although symbiosis between plants and fungi frequently occur. Mycorrhizae are mutualistic associations taking place at the root level (rizosphere), where the fungus profits by the carbohydrates assimilated from the plant, and the latter, in return, benefits from the fungal hyphae to improve its own mineral nutrient uptake by roots. Interestingly, mycorrhizae may elicit plant defence mechanisms by releasing chitin or chitosan fragments, sensing as PAMPs from the host perception machinery [12].

Nevertheless, another evident divergence, between the animal and plant kingdom, concerns the different relevance covered by the fungal diseases in animal

---

**Fig. 1** Pathogenic fungi of animals and plants; (a) *Candida albicans* in human oral mucosa (Periodic Acid-Shiff staining) and (b) *Uromyces appendiculatus* in bean leaf parenchyma (Evans’ blue staining)