Plants and their Pathogens

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Pathogen-induced ultrastructural alterations in plants

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Plants are constantly attacked by pathogens (e.g. fungi, viruses, bacteria). In order to cope with them several lines of defense have evolved in plants which protect them against negative effects induced by these invaders [1]. A successful defense of plants against pathogens results in an incompatible interaction where the pathogens are controlled, contained or defeated without the development of systemic symptoms. During compatible interactions plants are unable to control or defeat the pathogens which results in unlimited multiplication and systemic spread of the invaders which lead to physiological changes and to the development of symptoms throughout the infected organ or the whole organism. Many pathogens are able to undermine plant defense which can either result in a biotrophic interaction where the pathogen feeds on living plant cells or in a necrotrophic interaction where the pathogen tries to rapidly kill the host in order to feed from dead cells. Additionally, mutualistic interactions exist where both sides (microbes and plants) co-exist and profit from each other [1-3].

All of these interactions result in ultrastructural adaptations of the host cells either induced directly by the pathogens or indirectly by physiological changes of the plants. Electron and light microscopy allows the study of structural adaptations during plant pathogen interactions which can help to understand defense related processes on the cellular level. They also allow the identification and the diagnosis of the invader. This presentation will give an overview about ultrastructural adaptations of plants to different pathogens. It will demonstrate differences in ultrastructural changes between leaves of *Zea mays* infected with the biotrophic fungi *Ustilago maydis* (Figure 1a) and leaves of *Arabidopsis thaliana* infected with the necrotrophic fungal pathogen *Botrytis cinerea* (Figure 1b). The response of plant cells to the mutualistic fungi *Piriformospora indica* will be demonstrated in roots of *Arabidopsis thaliana* (Figure 1c). Furthermore this presentation will demonstrate differences in the ultrastructural adaptation of leaf cells to virus infections such as *Tobacco Mosaic Virus* (TMV) in *Nicotiana tabacum* (Figure 1d) and *Zucchini Yellow Mosaic Virus* (ZYMV) in *Cucurbita pepo* (Figure 1e). Finally, ultrastructual modifications in leaves of *Arabidopsis thaliana* plants infected with the hemi-biotrophic bacteria *Pseudomonas syringae* will be demonstrated (Figure 1f).

Light and electron microscopy can be used to visualize ultrastructural and physiological changes induced by these pathogens and to clearly identify and diagnose diseases [4]. Throughout this presentation different tools of plant sample preparation for light and electron microscopy will be presented which allow the visualization of reactive oxygen species (a commonly response of plants against pathogens), the quantification of differences in the relative amount of viral particles in plant organs, and the rapid identification and diagnosis of the plant disease. The rapid diagnosis of plant virus diseases can be of great significance in order to identify the viral agent and to limit the spread of the disease. In this presentation a method will be demonstrated that is based on microwave assisted plant sample preparation, negative staining methods, and cytohistochemical localization of viral coat protein and allows the rapid diagnosis of plant virus diseases in altogether about half a day by transmission electron microscopy.

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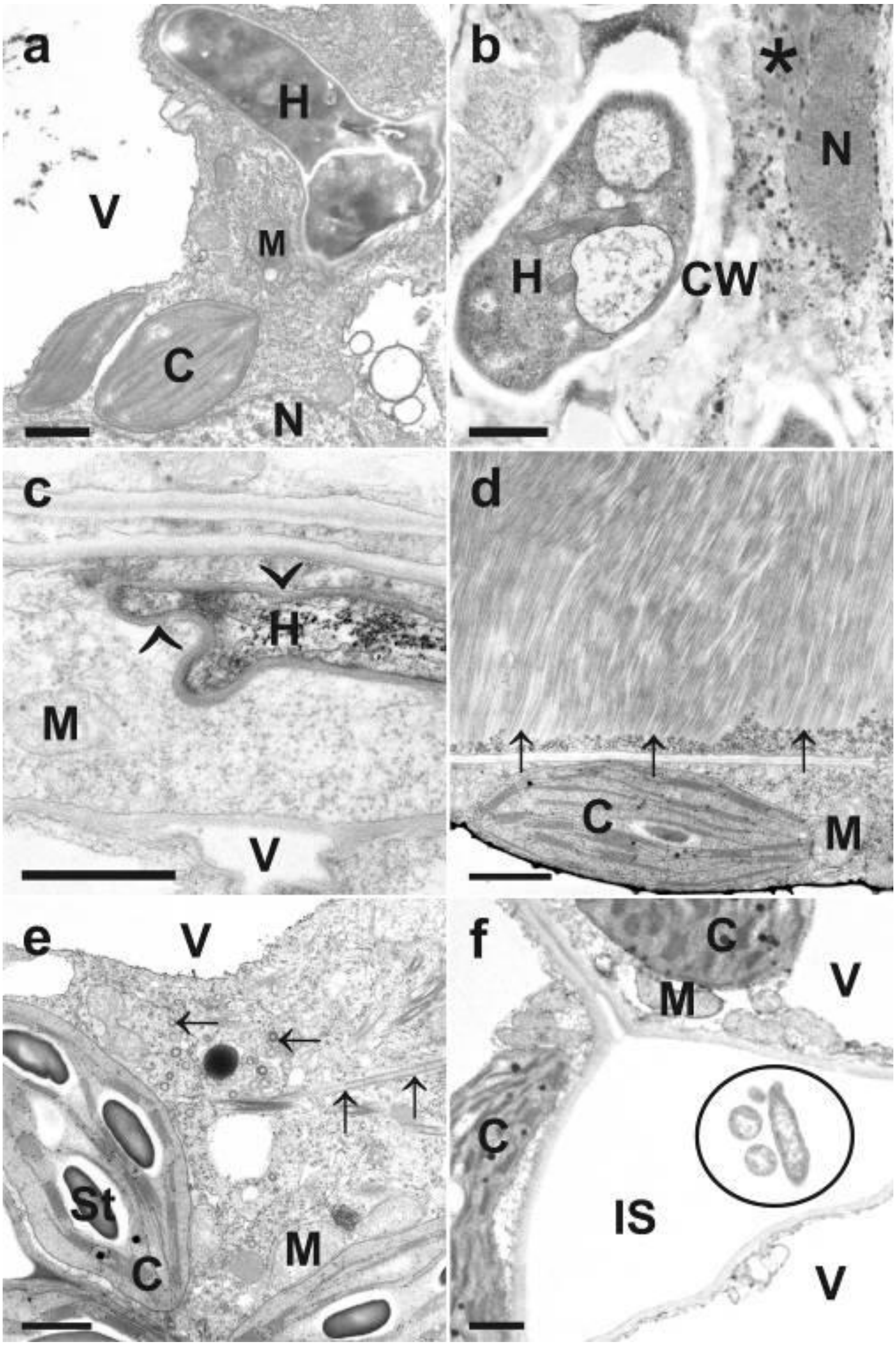

Figure 1. TEM-micrographs of selected ultrastructural modifications during plant pathogen interactions. Fungal hyphae (H) of the biotrophic basidiomycete *Ustilago maydis* are growing intracellulary in leaf cells of *Zea mays* without major alterations of the host cell (a). In opposite strong ultrastructural alterations can be observed at the final stages of *Botrytis cinerea* infection in leaves of *Arabidopsis thaliana* where only remnants of chloroplasts (star) can be found in the condensed cytosol (b). The mutualistic basidiomycete *Piriformospora indica* grows intracellulary within roots of *Arabidopsis thaliana* without damaging the host cell (c). Note the plasmamembrane around the hyphae (arrowheads in c). TMV- and ZYMV-infections are characterized by large areas of virions that accumulate in parallel form (arrows in d) and cylindrical inclusions in the cytosol, respectively (arrows in e). The hemibiotrophic bacteria *Pseudomonas syringae* grows and accumulates intercellulary (black circle) in *Arabidopsis thaliana* leaves without entering the host cells (f). C=chloroplasts with or without starch (St), CW=cell walls, IS=intercellular space, M= mitochondria, N=nucleus, V=vacuoles. Bars=1µm.