Chloroplast immunity: talk to your neighbor in an emergency

Eukaryotic cells maintain a highly organized subcellular compartmentalization that facilitates intracellular metabolism and signaling. In plants, organelles such as chloroplasts and mitochondria interact dynamically, particularly under stress conditions, through membrane contact sites (MCS) that enable molecular exchange, including metabolites, proteins, and lipids. While MCS have been recognized for decades, their functional significance in regulating plant physiology remains underexplored. Recent advances using live-cell imaging and genetic approaches have provided new insights into the intricate organization of MCS and their roles in biotic and abiotic stress responses.

A striking example of interorganellar communication is the formation of stromules—stroma-filled tubular extensions of chloroplasts—that facilitate molecular exchange with the nucleus. Stromules are emerging as critical structures in plant immune responses, mediating the transfer of reactive oxygen species (ROS) and other signaling molecules. However, the molecular mechanisms governing stromule dynamics and their impact on plant stress adaptation remain largely unknown. Using comparative transcriptomics, we have identified key regulatory genes involved in stromule induction, while proteomic analyses during immune responses have uncovered chloroplast-derived proteins that may translocate to the nucleus. Functional characterization of these candidates will provide novel insights into the role of chloroplast-nucleus communication in plant immunity, advancing our understanding of organelle-mediated stress signaling.