Plastid biogenesis and homeostasis

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Plastids are plant-specific organelles that affect various aspects of plant physiology. It is widely accepted that plastids have evolved from cyanobacteria via endosymbiosis (Gould et al. 2008). The most important driving force for the endosymbiotic conversion of a free-living cyanobacterium into an organelle was likely the acquisition of photosynthetic ability of cyanobacteria by the host cell, thus transforming the host cell into an autotroph. However, plastids attained the status of an essential organelle during evolution, as these house a number of crucial cellular processes and also serve as a storage place of ions, such as Fe and Cu, in addition to the reactions involved in photosynthesis (Padmanabhan and Dinesh-Kumar 2010). The importance of plastids in plant biology is evident from the fact that a mutation in any one of the many genes involved in plastid biogenesis leads to embryonic lethality or severe defects in plant growth and development (Yu et al. 2004).

Because of the importance of plastids in plant physiology, numerous studies have been carried out to elucidate the different aspects of plastid biology. An important topic of research is the evolution of plastids. In fact, this is one of the most mysterious events in the evolution of eukaryotic cells, together with the evolution of mitochondria from α -proteobacteria (Gould et al. 2008). The details of how a free-living cyanobacterium converted into an organelle in eukaryotic cells remain largely unknown. During endosymbiosis, a large number of genes were transferred from the endosymbiont to the host nuclear genome (Martin et al. 1998; Bhattacharya et al. 2007). Many of proteins encoded by these genes are imported into plastids after translation in the cytosol. Studies on the mechanism of protein import into chloroplasts have revealed components of the protein translocon at the outer and inner plastid membranes and the cytosolic cargo receptor as well as their action mechanisms

at the molecular and biochemical levels (Richardson et al. 2014; Kim et al. 2015). Additionally, small critical motifs in the transit signal peptides have been identified, and their roles in protein import into chloroplasts have been elucidated (Lee and Hwang 2018).

Another unique property of plastids is their functional diversity, depending on the cell type. One important prerequisite for the functional diversity of plastids is the variation in their protein constituents. Ubiquitin/proteasome-dependent protein degradation plays a crucial role in plastid development (Ling and Jarvis 2015). In a given cell type, the status or functionality of plastids changes according to the plant status or environmental conditions (Watson et al. 2018). Investigation of the dynamic changes in plastid function would enhance our understanding of the role of plastids in plant physiology. The plastid/chloroplast communicates with the nucleus for the expression of nuclear encoded plastid proteins. One such communication is retrograde signaling, and many components involved in this signaling have been identified and elucidated at the molecular level (Chan et al. 2016). However, our understanding of the communication between chloroplasts and nucleus is incomplete, as the exact role of these signaling molecules remains unknown.

Recently, research on plastids is gaining a new momentum to face the challenges imposed by global warming. Continued rise in temperature could greatly damage plant productivity by decreasing photosynthetic efficiency (Mathur et al. 2014). To overcome the negative impact of high temperature, plants have evolved several strategies; one such strategy is C4 photosynthesis (Schulze et al. 2013). C4 plant species, such as maize (*Zea mays*), exhibit Kranz anatomy, which is characterized by the presence of two different photosynthetic cell-types, mesophyll and bundle sheath cells. However, the C4 plant species *Bienertia sinuspersici* possesses a single cell type with two different types of chloroplasts (Stutz et al. 2014). Attempts have been made to introduce the C4 photosynthetic system into C3 crop plants to increase crop yield under global warming (Schuler et al. 2016).

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The chloroplast, a form of the plastid, also gained attention in the production of recombinant proteins. Chloroplasts occupy the second largest cellular space, after the lytic vacuole, in leaf cells. A foreign gene integrated in the chloroplast genome is expressed to an extremely high level (Daniell et al. 2016). Additionally, proteins can be targeted to chloroplasts after translation in the cytosol (Meyers et al. 2008). Currently, many approaches are being explored to use chloroplasts for the storage of plant-produced recombinant proteins.

In this special issue, we summarize seven articles that cover various topics of research described above. Sadalia et al. (2019) described the differentiation of chromoplasts and other plastids in plants. Kim et al. (2019) reviewed the recent discovery of protein targeting to the outer envelope of the plastid. Another paper by Pesaresi and Kim (2019) covered the role of GUN1 in biogenic retrograde signaling. Cha et al. (2019) demonstrated a novel role of GIGANTIA in the regulation of chloroplast biogenesis under abiotic stress. Mermond et al. (2019) describes the role of SQUAMOSA promoter binding protein-like 7 in the homeostasis of Cu ion in chloroplasts. Wimmer et al. (2019) described the differential targeting of proteins to the dimorphic chloroplasts in *B. sinuspersici*. Finally, Muthamilselvan et al. (2019) covered recent advances in the utility of chloroplasts for recombinant protein production in plants. Thus, in this special issue, we review various topics related to plastid biology. This information will serve as a useful reference material for researchers investigating plastid biogenesis and homeostasis.

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