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Programmed Cell Death in Plants

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SUMMARY

Programmed cell death (PCD) is defined as an active process which is directed at the elimination of redundant, misplaced or damaged cells and maintenance of multicellular organisms through genetic, biochemical, and morphological development. During development and in response to pathogenic infection, cell death in higher plants has been broadly perceived in liable patterns. It is essential for plant growth & survival and plays a vital part in development of embryo, formation and maturation of various cell types and tissues, and reaction/adaptation of plant to environmental situations. Plants use PCD both in the way of development and in response to osmotic, thermal, and oxidative stresses and in defence from pathogens. PCD also needed as one of the survival mechanisms in plant in certain occurrences of biotic and abiotic stresses like disease, water stress, salt and heat stress.

INTRODUCTION

Programmed cell death (PCD) is widely accepted as a fundamental cellular process in plants and is involved in defence, development and response to stress. PCD has been well-defined as a sequence of potentially interruptible events that causes a controlled and organized destruction of the cell (Lockshin and Zakeri, 2004). Plants use PCD both in the course of development (for example, during xylem formation, seed germination, prevention of self-pollination, and senescence) and in response to osmotic, thermal, oxidative stresses and in defense from pathogens. Additionally, PCD is also observed in certain developmental processes as well where defined cells die and the dead cells take over their assigned function such as tracheary cells, sclerenchyma fibres and cork cells in plants. In correspondence with the name “apoptosis”, that comes from plant kingdom from old Greek “apoptosis” that formerly means ‘the loss of petals or leaves’. Ultra structural studies originally described two distinct types of cell death by Kerr *et al*., 1972, *viz*., apoptosis and necrosis. Apoptosis was initially described in very specific morphological terms (Kerr *et al*., 1972) and still is categorised by cell shrinkage, nuclear condensation and fragmentation, and ultimately the breakup of the cell into ‘apoptotic bodies’ (Adrain and Martin, 2001). In distinction to apoptosis, necrosis has been described as an uncontrolled sort of cell death which normally follows overwhelming cellular stress where the cell is incapable to stimulate its apoptotic pathways. In necrosis, swelling somewhat than shrinkage is the defining feature of the morphological change. The different pathological feature of necrosis and apoptosis was described in Table 1.

Purpose of PCD

1.It is necessary for effective development and growth of complex multicellular organisms.
2.It regulates the frequency of cell division.
3.Shaping of cells, tissues and organs.
4.It reins the cell populations and defense against invading microbes.
5.It is needed to destroy the cells that represent a threat to the reliability of the organism.
Examples: Cells infected with virus
Cells with DNA damage

Table 1: Pathological features of necrosis and apoptosis

Features	Necrosis	Apoptosis
Pattern of death	Assembly of neighboring cells	Distinct cells
Cell size	Swelling	Shrinkage
Plasma membrane	Smoothing	Blebbed
Mitochondria	Swelling disordered structure	Contents released into the cytoplasm and contracted
Organelle shape	Disruption	Apoptotic bodies
Nuclei	Membrane disruption	Clumps and fragmented
DNA degradation	DNA fragmentation is random or smeared	Ladder like- DNA fragmentation
Cell degradation	Macrophage invasion Inflammation	Phagocytosis No inflammation

Two major classes of plant PCD

1. Autolytic

It is a type of developmental PCD and rapid cytoplasm clearance after tonoplast rupture. For example, PCD that arises during the formation of the male and female zygotes, in seeds (except endosperm in cereals), in embryonic structures, and through development of roots and shoots. Mild abiotic stress, like lack of oxygen (induces aerenchyma in roots), and drought (advances leaf yellowing and other senescence processes).

2. Non-autolytic

It is a type of hypersensitive response (HR)-related PCD and also known as necrotrophic PCD, i.e., the absence of a rapid clearance of the cytoplasm. This PCD class is primarily found in PCD that is due to plant–pathogen interactions. Other examples of PCD where death is revealed to occur earlier to tonoplast rupture, where tonoplast rupture does not occur, or where tonoplast rupture is not followed by complete clearance of the cytoplasm. Endosperm in cereal seeds is an example of no tonoplast rupture.

Programmed Cell Death Pathway

Apoptosis is prompted by multi-signal pathways and regulated by multi-complicated extrinsic and intrinsic ligands. The process of apoptosis is controlled by diversity cell signals pathway and involved in regulation of cell fate death or survival. There are two major apoptosis pathways distinguished according to whether caspases are involved or not.

1. Extrinsic Pathway

In extrinsic pathway, the source of signal originates from outside the cell and many receptors are available outside the cell. Death receptor which is either FAS or TNFR (Tumour Necrosis Factor Receptor). So, there is always a ligand which can binds with death receptor, it is known as Death ligand (Fas ligand). Since, these particular involves the death receptor and ligand then it is also known as Death Receptor Pathway or Extrinsic Pathway. Three death receptor (DR) are joined together and formed death domain (DD) in the cytoplasm of the cell. After that some adaptor protein come to attach DD and called as Fas Associated Death Domain (FADD). The basic function of FADD is the activation of procaspase 8. Procaspase-8 are initiator caspases. FADD activates procaspase 8 and then converted to activated caspase-8. These activated caspase-8 is further activated caspase-3,6 and 7. These executioner caspases actually break the nucleus by activation of endonucleases and they also break cytoskeleton.

There is cell breakdown of nucleus and cytoskeleton and formation of blebbing, later they formed apoptotic bodies. These apoptotic bodies are membrane bound structure which contain fragment of nucleus and cytoskeleton. There will be no inflammatory reaction.

2. Intrinsic Pathway/Mitochondrial Pathway

In intrinsic pathway, origination of pathway is inside the cell, that's why it is called as intrinsic pathway. Cytochrome C is present inside the mitochondria and normally located in the intermembrane space. Once they come out from the mitochondria with any reason, they are the one which activates apoptosis. Once Cyt-C are released into the cytoplasm they combine a protein called (APAF-1) Apoptosis Activating Factor-1. The combination of these two form results into the formation of Apoptosome. Apoptosome is a complex form activates procaspase-9 and converted into Activated caspase-9. It activates caspase 3, 6 &7 (these are executioner caspases). These executioner caspases break down the nucleus by activation of endonucleases and they also break down cytoskeleton.

Programmed Cell Death in Response to Abiotic and Biotic Stresses

Abiotic stresses comprise toxins like salinity, metals, herbicides and gaseous pollutants, including reactive oxygen species (ROS), also as deficit of water and water logging, high, coldness and extreme illumination. It may also result in stunted growth, followed by death of part of the plant. Hence, cell death in abiotic stress could be a part of a regulated process to make sure survival. PCD leading to the formation of a protective layer that functions to block high irradiance and trap humidity (Greenberg, 1996). Several studies have revealed the induction of PCD in plants in response to pathogen attack, indicating that PCD plays central role in pathogenesis (Goodman and Novacky, 1994). At least two sorts of necrobiosis occur following the infection of a plant with a pathogen e.i., hypersensitive response and disease symptoms.

CONCLUSION

The method of PCD is important for confirming the right improvement of plants also as confirming a strong defense response besides invading pathogens. Therefore, main influences will come from research concentrated specifically on how cell death occurs with in sole biological contexts (Hypersensitive response, etc.) that are of interest to plant biologists and important for improving agriculture.

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