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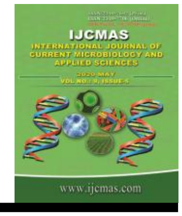

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Plant Viruses – A Causative Agent for Biochemical and Physiological Alteration in Plants

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A B S T R A C T

Agriculture plays a vital role in the Indian economy. Over 70 percent of the rural households depend on agriculture. Though India is one among the largest producers of most of the agricultural crops, but its rank is extremely low in terms of productivity. In addition to it, many types of environmental stresses both biotic and abiotic affect the plants and produce characteristic changes in its physiology and metabolic processes. Among the stresses, attack by pathogens causes many biochemical changes. It results in destructive effects on plant health which in turn leads to reduced crop yield and quality. The aim of this review is to give brief information on biochemical and physiological alterations in plants due to the infection of viruses.

Introduction

Plants are under permanent attack by several pathogenic agents, such as fungi, oomycetes, nematodes and viruses. These pathogens are responsible for important agricultural losses that limit worldwide food production. Viral diseases can represent approximately 50% of the new emerging diseases affecting plants and new plant viruses are being discovered every day (Whitfield *et al*, 2015). Plant viruses are classified as DNA or RNA viruses according to Baltimore's viral classification (Baltimore 1971). While both RNA and DNA plant viruses lead to lower crop production, RNA viruses are the most abundant (Laliberte and Sanfaçon 2010; Souza *et al*, 2019).

All viruses are obligate parasites that depend on the cellular machinery of their hosts to reproduce. Viruses are not active outside of their hosts, and this has led some people to suggest that they're not alive. All types of living organisms, including animals, plants, fungi, and bacteria are hosts for viruses, but most viruses infect only one type of host (Gergerich and Dilja, 2006).

Viruses cause many diseases of international importance. Amongst the human viruses, smallpox, polio, influenza, hepatitis, human immunodeficiency virus (HIV-AIDS), measles and the SARS corona virus are particularly well known. While antibiotics can be very effective against diseases caused by bacteria, these treatments are ineffective against viruses and still under research. Its most control measures rely on vaccines or relief of the symptoms to encourage the body's own defense system.

In plants, viruses cause many important diseases and restricted the production of important vegetable crops in tropical, subtropical, and temperate regions. Infected plants may show a range of morphological symptoms depending on the disease but often there is leaf yellowing, leaf distortion, streaking and stunting, vein clearing and mosaic incidence. The disease can completely destroy the crop under favourable conditions leading to yield loss (Radwan *et al*, 2007).

In this review, we briefly describe the biochemical and physiological changes occurred due to the incidence of plant viruses.

Importance of biomolecules and its impact on plant viral infection

Two major classes of metabolites exist in plants. The primary metabolites directly involved in normal growth, development, and reproduction. It usually performs a physiological function in the organisms. The primary metabolites are carbohydrates, proteins, amino acids, lipids, and fatty acids. Secondary metabolites play multiple essential roles in normal plant physiology. They are mainly synthesized at need, and function primarily in adaptation to biotic and abiotic stresses. As for the biotic aggressions, these metabolites protect plants against pathogens such as virus, mycoplasma, bacteria, and fungi, against predators-both insect and mammal herbivores-rival species, and plant competitors (Korkina *et al*, 2017).

Generally, virus infection in plants induced numerous genetic, metabolic and physiological changes. In many cases, their protective mechanisms involve an inducible defense system. The ability of plants to invoke such defense reaction is presumed to be mediated by an initial recognition process that involves detection of certain unique signal molecules of incompatible pathogens by receptor – like molecules in plants, resulting in a cascade of biochemical events that leads to the expression of resistance and susceptibility to a disease (Ryals *et al*, 1994).

Host - Pathogen interactions are presumed to generate signals that activate nuclear genes involved in plant defense response leading to the induction of stress - related enzymes, differential expression of proteins and release of free amino acids and the associated accumulation of high levels of phenolic compounds. Antimicrobial phytoalexins such as sesquiterpeneoids, isoflavanoids, coumarines, acetylenic and phenolic compounds also contribute to multilayered plant defense system (Keen, 1992; Chaterjee AND Ghosh, 2008).

In general, pathogen-triggered responses are associated with increasing demands for energy, reducing equivalents, and carbon skeletons that are provided by primary metabolic pathways (Berger *et al*, 2007; Bolton, 2009). While metabolic changes associated with infection by fungi and bacteria have been widely documented

(Bolton, 2009), little is known about the effect of plant viruses on host primary metabolites and the influence of these changes on the onset of infection and symptom expression. However, a compatible virus infection in plants is a multifaceted and controlled process whereby the virus appropriates cellular functions in order to replicate and move throughout the plant. In this complex interaction, plants accommodate their metabolism to restrict virus infection and to counteract potential adverse effects caused by the virus (Whitham *et al*, 2006; Calvino *et al*, 2014).

Importance of chlorophyll and its impact on plant viral infection

Chlorophylls are unique pigments with green color and are found in diverse plants, algae, and cyanobacteria (Inanc, 2011). The main source of life on earth is the solar energy that is captured by green plants, algae, and various photosynthetic bacteria. Although there are different photosynthetic pigments such as carotenoids and phycobilins which entrap solar radiation, chlorophyll is the most important of these molecules. It converts solar energy into chemical energy that is used to build essential carbohydrate molecules (glucose) which are used as food source for the whole plant (Hynninen and Leppakases, 2002; Pareek *et al*, 2018) (Fig. 1).

The chloroplast is one of the most dynamic organelles of a plant cell. It carries out photosynthesis, synthesizes major phytohormones, plays an active part in the defence response and is crucial for interorganelle signaling. The chloroplast, a prime target for viruses, undergoes enormous structural and functional damage during viral infection. Indeed, large proportions of affected gene products in a virus-infected plant are closely associated with the chloroplast and the process of photosynthesis (Bhattacharyya and Chakraborty, 2018). The most common viral symptom during viral infection of plants is leaf chlorosis, reflecting altered pigmentation and structural change of chloroplasts. Viral influence on chloroplast structures and functions usually leads to depleted photosynthetic activity.

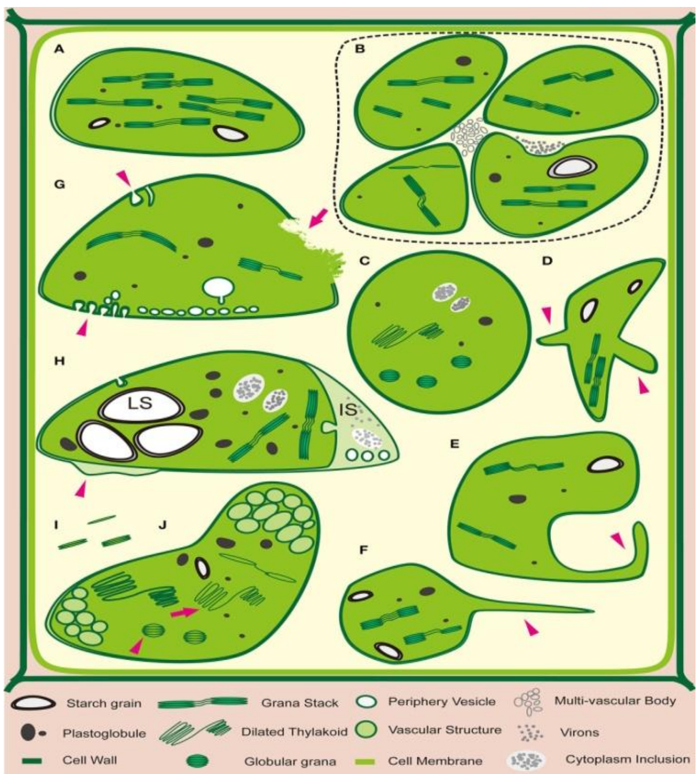
A series of typical changes followed by chlorotic symptoms imply the occurrence of chloroplast-virus interactions. These changes were studied by different researchers and are documented as, fluctuation of chlorophyll fluorescence and reduced chlorophyll pigmentation, inhibited photosystem efficiency, imbalanced accumulation of photo assimilates, changes in chloroplast structures and functions, repressed expression of nuclear-encoded chloroplast and photosynthesis-related genes (CPRGs) and direct binding of viral components with chloroplast factors (Zhao *et al*, 2016).

Similarly, the chloroplasts malformations were also occurring. It was studied by various scientists and exhibited the results are as follows: overall decrease of chloroplast numbers and chloroplast clustering, a typical appearance of chloroplast, such as swollen or globule chloroplast, chloroplast with membrane-bound extrusions or amoeboid-shaped chloroplast, generation of stromule (a type of dynamic tubular extensions from chloroplast), irregular out-membrane structures such as peripheral vesicle, cytoplasmic invagination, membrane proliferations and broken envelope, changes of content inside the chloroplast such as small vesicles or vacuoles in stroma, large inter-membranous sac, numerous, and/or enlarged starch grains, increase in the number and size of electron-dense granules /plastoglobules /bodies, unusual photosynthetic structures such as disappearance of grana stacks, distorted, loosen, or dilated thylakoid and the disappearance of stroma; and completely destroyed chloroplasts and disorganized grana scattering into the cytoplasm.

Activities of antioxidant enzymes in response to virus infection

Once plants subjected to biotic or abiotic stresses, often it results in the production of reactive oxygen species (ROS) such as superoxide ion (O_2^-), hydrogen peroxide(H_2O_2) and the hydroxy radical (OH^*). To develop the danger posed by the presence of cellular oxidants, plant cells have evolved complex defense mechanisms. These include the synthesis of antioxidants such as ascorbate and glutathione and an increase in the activity of enzymes such as ascorbate and glutathione peroxidases, glutathione reductase, catalase and superoxide dismutase (SODs) (Clarke *et al*, 2002).

It has been reported that, the transcriptional activation of defense genes encoding phenyl propanoid pathway enzymes, lytic and antimicrobial pathogenesis (PR) proteins, and development of the hypersensitive response (HR). The outcome of HR is manifested by dry, necrotic lesion at the infection site that is clearly delimited from surrounding healthy tissue and is thought to contribute to the limitation of pathogen spread (Sarkar *et al*, 2011).



(A) Normal chloroplast (B) Aggregated chloroplasts (C) Swollen chloroplast
(D) Chloroplast with membrane- bound extrusions (E) Amoeboid-shaped chloroplast
(F) Chloroplast with stromule (G) Chloroplast with irregular out-membrane structures
(H) Chloroplast with abnormal content changes (I) Disorganized grana scattering into the cytoplasm (J) Chloroplast with unusual photosynthetic structures
Source: Zhao *et al*, 2016)
Fig.1 Ultrastructure of chloroplasts induced by virus infection

In plants, virus infection induced numerous genetic, metabolic and physiological changes including changes in the photosynthetic apparatus in chloroplasts. Virus diseases that have emerged in the past two decades limit the production of important vegetable crops and are responsible for losses in crop yield and quality in all the parts of the world.

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