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RESEARCH ARTICLE OPEN ACCESS

Disruption of The Physiological State of Plants Under the Influence of Phytopatogeneous Microorganisms

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ABSTRAC

Phytopathogenic microorganisms — bacteria, fungi, viruses, and nematodes — cause various diseases in plants. As a result of their infection, serious disturbances occur in the physiological systems of plants: photosynthesis, water and nutrient metabolism, hormone balance, antioxidant system, synthesis of secondary metabolites, and other processes are disrupted. This article theoretically analyzes the physiological disorders caused by phytopathogens. The complex molecular and cellular interactions between the plant and the pathogen are highlighted.

Keywords: Phytopathogen, plant physiology, oxidative stress, photosynthesis, hormonal system, secondary metabolites.

INTRODUCTION

Water plays a crucial role in the life of plant. It is the most abundant constituents of most organisms. Water typically accounts for more than 70 percent by weight of non-woody plant parts. The water content of plants is in a continual state of flux. The constant flow of water through plants is a matter of considerable significance to their growth and survival. The uptake of water by cells generates a pressure known as turgor. Photosynthesis requires that plants draw carbon dioxide from the atmosphere, and at the same time exposes them to water loss. To prevent leaf desiccation, water must be absorbed by the roots, and transported through the plant body. Balancing the uptake, transport, and loss of water represents an important challenge for land plants. The thermal properties of water contribute to temperature regulation, helping to ensure that plants do not cool down or heat up too rapidly. Water has excellent solvent properties. Many of the biochemical reactions occur in water and water is itself either a reactant or a product in a large number of those reactions.

The practice of crop irrigation reflects the fact that water is a key resource limiting agricultural productivity. Water availability likewise limits the productivity of natural ecosystems). Plants use water in huge amounts, but only small part of that remains in the plant to supply growth. About 97% of water taken up by plants is lost to the atmosphere, 2% is used for volume increase or cell expansion, and 1% for metabolic processes, predominantly photosynthesis. Water loss to the atmosphere appears to be an inevitable consequence of carrying out photosynthesis. The uptake of CO_2 is coupled to the loss of water. Because the driving gradient for water loss from leaves is much larger than that for CO_2 uptake, as many as 400 water molecules are lost for every CO_2 molecule gained [7].

The research group of Plant Physiology faces different aspects of basic and applied plant research, with particular reference to those aspects involved in technological transfer to industries. Research is performed at the Centre for Innovation were three thematic laboratories are equipped for Advanced Plant Physiology studies.

Metabolomics: we isolate and characterize bioactive plant products and we evaluate their possible use in nutraceutical, pharmaceutical and biomedical applications as well as their potential as indicators for detecting environmental changes by using plants as biosensors.

Genomics: we study the expression and function of genes in plants undergoing biotic and abiotic stresses. Plant molecular biology studies are dealing with gene characterization and cloning, differential expression and quantitative analysis.

Geomagnetic field laboratory: a triaxial Helmholtz coil system placed in a environmentally controlled room allows the study of the effects of the geomagnetic field on plant growth, development and evolution.

The group of Plant Physiology collaborates actively with many international research centres belonging to the the most prestigious European and Japanese universities [11].

Plants are exposed to various biotic and abiotic factors in the environment. The most dangerous of the biotic factors are phytopathogenic microorganisms. They penetrate plant tissues, use nutrients, and disrupt the normal physiological processes of the host plant during their vital activity. Phytopathogens disrupt photosynthesis, respiration, osmotic balance, transpiration, changes in cell wall structure, and signaling systems. These processes often result in deterioration of plant health and reduced productivity [1].

Fungi are among the most common phytopathogens. For example, species such as Fusarium, Alternaria, Botrytis, and Magnaporthe invasively occupy plant tissues and damage physiological processes by producing enzymes and toxins (Pic.1).

Pic.1. Symptomatic signs caused by phytopathogenic microorganisms in plants

Pseudomonas syringae, Xanthomonas campestris, and Erwinia species enter plant cells and produce phytotoxins that dissolve the cell wall and disrupt the metabolic balance within the cell (Pic.2) [2].

Pic.2. Disease caused by bacteria

Viruses take over the genetic machinery of plants and control protein synthesis within the cell. Tobacco mosaic virus (TMV) and Tomato spotted wilt virus (TSWV) cause serious damage to photosynthesis and hormonal balance (Pic.3.) [3,4]

Pic.3. Viral diseases

Many phytopathogens disrupt chloroplast structure, reduce chlorophyll content, and reduce the efficiency of photochemical reactions. For example, Alternaria alternata infection causes necrotic spots on leaves and significantly reduces photosynthesis. As a result of damage to root and xylem tissues by fungi or nematodes, the transpiration process is disrupted, the water supply system fails. This is accompanied by rotting, wilting, and a lack of tolerance to light stress[5].

Phytopathogens affect the levels of phytohormones such as salicylic acid (SA), jasmonic acid (JA), abscisic acid

(ABA), and ethylene (ET). For example, Fusarium infection increases ABA levels, which ultimately leads to the closure of cell pores. During infection, reactive oxygen species (ROS) increase in plant cells. They damage cell membranes and oxidize DNA and proteins. Plants combat this stress with enzymes such as superoxide dismutase (SOD), catalase (CAT), and ascorbate peroxidase (APX). Diseased plants produce flavonoids, phenols, alkaloids, and phytoalexins for defense. However, these processes require a lot of energy and negatively affect plant growth.

Plants have natural defense mechanisms. The following are important among them:

• Cellular responses: Cell wall thickening, callose synthesis.

• Genetic responses: Expression of PR (Pathogenesis-Related) genes.

• Signaling molecules: Activation of the defense system with the participation of SA, JA, ET.

• Hypersensitive response (HR): Prevention of pathogen spread by rapid death of infected cells[6].

Transpirational stream. During rapid evapotranspiration, the rate of water transport in xylem is about 4 mm. Water lost by transpiration must be replenished by the absorption of an equivalent amount of water from the soil. One sunflower plant "imbibes" and "transpires" 17 times more water than a human every 24 h. A single maize plant transpires approximately 150 L of water in its average lifespan. CO2 uptake for photosynthesis requires moist surface but when water is exposed, it gets evaporated. Plants face this challenge of taking more carbon dioxide and at the same time loss of water. Plants lose 400–600 molecules of water while gaining 1 molecule of carbon dioxide. Thus, both photosynthesis and transpiration are inseparable processes the in life of green plants. Water has high latent heat of vaporization. At 30 °C, 1000 g of water absorbs 580 Kkal of heat from its environment. Large amount of water is being evaporated from plants and the heat required for vaporization is being drawn from leaf. It helps plants to maintain the temperature and tolerate harsh environmental pressures. The main advantage of transpiration is creation of suction pressure for uptake of water and minerals from the soil. Once plants build up enough transpirational pull during early hours of the day, water uptake by the plants begins. "Transpiration is a necessary evil" as it is inseparable from photosynthesis[6].

Plants have a distinct vascular system (xylem and phloem) which helps in transporting nutrients and water from roots to all the parts of the plant through translocation.

Transport of water and nutrients in rooted plants is unidirectional or multi-directional. Modes of transportation can either be passive which occurs through diffusion, facilitated diffusion to be precise or can be through active mode carried out by specific membrane proteins which are called pumps.

Water plays a pivotal role in carrying out physiological activities, hence understanding the importance of plant-water relations is essential.

The concept of water potential helps in comprehending the water movement through terms such as- Solute potential and pressure potential.

At the cellular level, osmosis takes place in plants which allows movement of molecules in and out of the cells.

Transpiration is another aspect crucial in the life cycle of plants.

The process of plant development starts right from germination under favourable environmental conditions.

Generally, plant growth is indeterminate as they retain their capacity to grow throughout their lives because of the presence of meristems. The growth of plants is, however measurable through parameters such as – dry weight, increase in fresh weight, length, area, volume, cell number etc.

The period of plant growth is categorized into three phases – meristematic, elongation and maturation.

The growth rate can be determined quantitatively in 2 ways – absolute growth rate and relative growth rate.

The growth of plants is controlled by plant growth regulators.

Plants also produce compounds such as phytochromes that are light sensitive and stimulate the growth of the plant in response to environmental signals [8].

CONCLUSION

Phytopathogenic microorganisms cause a wide range of physiological disorders in plants. These disorders have a serious impact on plant health, growth, and productivity. Phytopathogen-plant interactions involve complex processes at the molecular and cellular levels. Their in-depth study will expand the possibilities of creating genetically resistant varieties and developing environmentally friendly protective agents.

Despite their great diversity in form and size, all plants carry out similar physiological processes. As primary producers, plants convert solar energy to chemical energy. Being nonmotile, plants must grow toward light, and they must have efficient vascular systems for movement of water, mineral nutrients, and photosynthetic products throughout the plant body. Green land plants must also have mechanisms for avoiding desiccation. The major vegetative organ systems of seed plants are the shoot and the root. The shoot consists of two types of organs: stems and leaves. Unlike animal development, plant growth is indeterminate because of the presence of permanent meristem tissue at the shoot and root apices, which gives rise to new tissues and organs during the entire vegetative phase of the life cycle. Lateral meristems (the vascular cambium and the cork cambium) produce growth in girth, or secondary growth. Three major tissue systems are recognized: dermal, ground, and vascular. Each of these tissues contains a variety of cell types specialized for different functions. Plants are eukaryotes and have the typical eukaryotic cell organization, consisting of nucleus and cytoplasm. The nuclear genome directs the growth and development of the organism. The cytoplasm is enclosed by a plasma membrane and contains numerous membrane-enclosed organelles, including plastids, mitochondria, microbodies, oleosomes, and a large central vacuole. Chloroplasts and mitochondria are semiautonomous organelles that contain their own DNA. Nevertheless, most of their proteins are encoded by nuclear DNA and are imported from the cytosol [9].

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