PLANT PHYSIOLOGY AND ENVIRONMENT: AN INTRODUCTION

Jari P.T. Valkonen
Swedish University of Agricultural Sciences, Uppsala, Sweden, and Plant Pathology, University of Helsinki, Finland.

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Summary

This chapter is devoted to the various environmental factors affecting plant physiology. A few basic facts about plant physiology, such as the role of water, photosynthesis and nitrogen fixation, are reviewed first since these plant functions provide the basis for life of the other higher organisms on Earth. Plants convert solar energy to a form usable for animals and humans. They also produce the oxygen required by humankind and the animal kingdom for life, and needed for the endless number of applications and technologies that the human beings have developed to ease their daily lives. Therefore, for life on Earth, it is of fundamental importance that the environment remains suitable for plants. However, changes in the environment are continuous and sometimes irreversible. Often, but not always, the changes are caused by man. For these reasons, it is important to understand how different environmental factors affect plant physiology and utilize the knowledge to maintain or re-create conditions and environments favorable for flora.

The sections of this chapter describe several physiological aspects without describing their molecular genetic basis. Therefore, at the end of this introductory section, some of the latest developments in molecular research on plant physiology are briefly reviewed.

1. Basic Physiology of Plants

All biochemical reactions in plants and other living organisms take place in aqueous solutions. Also, water is required for transportation of organic substances and minerals between cells. In plants, specialized tissues formed by phloem and xylem cells constitute the so-called vasculature used as the transport route between different parts of the plant. Herbaceous plants need water to create turgor pressure, which in turn is needed to keep stems and leaves upright. Evaporation of water, i.e. conversion of water to a gaseous form (steam), requires energy and is used to control temperature in plant tissues. The essential functions of water in plants are dealt with in *Water Relations in Plants*.

Plants are essential for life on Earth since they are largely responsible for converting solar energy into a biochemical (organic) form. This reaction is called photosynthesis. It takes place on membrane structures (thylakoids) in cellular organelles called chloroplasts. It involves one molecule of carbon dioxide (CO_2) and two molecules of water (H_2O), which react with the help of solar energy to form one molecule each of a carbohydrate (CH_2O), water, and oxygen (O_2) (See Figure 1.).

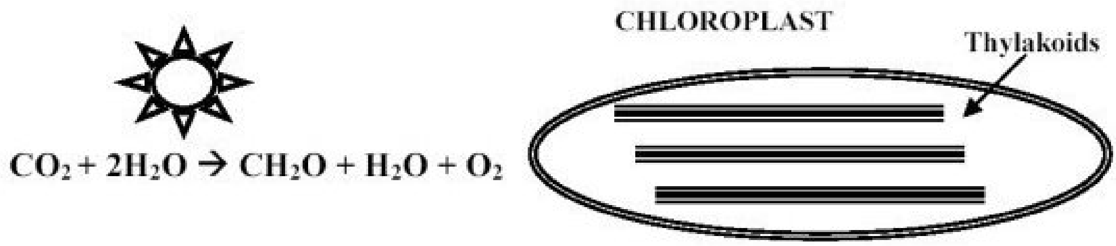

Figure 1. One molecule of carbon dioxide (CO_2) and two molecules of water (H_2O), which react with the help of solar energy to form one molecule each of a carbohydrate (CH_2O), water, and oxygen (O_2).

The reaction requires 4.8 x 10^5 J of energy per one carbohydrate molecule. Besides vascular plants, ferns and bryophytes (mosses and liverworts), some green algae and cyanobacteria carry out photosynthesis. It is estimated that, in every second, six million kilograms of carbon is photosynthetically fixed to carbohydrate. Carbohydrates, in turn, provide the source of energy to all other organisms. The biochemistry of photosynthesis and the importance of photosynthesizing organisms to life of Earth are discussed in *The Functions of Chlorophylls in Photosynthesis.* The most notable enzyme involved in photosynthesis is RUBISCO (ribulose-1,5-biphosphate carboxylase). It is involved in the metabolic pathway (Calvin cycle) that coverts carbohydrates to sugars. However, at high oxygen concentration, RUBISCO catalyses an opposite, wasteful reaction called photorespiration, in which carbohydrates are degraded and carbon dioxide is released.

Nitrogen is an essential component of amino acids and proteins, among which enzymes are a vital group of catalysts. These biomolecules are the cornerstones for all life. Genes ruling the biological functions in living organisms direct the synthesis of amino acids, which form peptides and proteins. They, in turn, are used to express the biological functions. Animals and humans need to acquire essential amino acids in the diet, and most of them can be obtained from plant products. However, the majority of plants cannot utilize nitrogen in the gaseous form (N_2), in which it occurs in the atmosphere. Therefore, N_2 needs to be reduced to ammonia (NH_3), a task which is carried out by bacteria. Some plants have acquired the ability to fix atmospheric nitrogen with the help of microbes living in a symbiotic relationship with them (see *Biological Nitrogen Fixation with Emphasis on Legumes*).

2. Environmental Factors Affecting Plant Physiology

The *physical environmental factors* affecting plant physiology include the soil, atmosphere and climate. They show extreme variation between different geographic areas. Perhaps the most demanding climatic conditions are those where the plant needs to tolerate extreme coldness and freezing, but also high temperatures, depending on the season. The boreal zone is an example of such extremely stressful conditions for plants. The plants have adapted their physiology to withstand sudden freezing (frost tolerance), and to acclimatize for the long cold periods when they may be partially or fully covered by snow (winter hardiness). Low metabolic activity (dormancy) is needed for survival over the period with the most extreme conditions (see *Phenology of Trees and Other Plants in Boreal Zone under Climatic Warming).*

The on-going changes in the global climate which occur at a much more rapid rate than the speed of evolutionary adaptability of plants, may be a serious threat to plants in many growing zones on the Earth. These changes will also affect food production. The changes are largely caused by man. The chemical composition of the atmosphere has changed, and this affects temperature. The so-called greenhouse gases, acid rain and air pollutants also have direct effects on plants. In some cases they may increase the growth of plants and productivity, but in most cases they seem to be harmful. They increase photorespiration, induce stress responses, and may cause cellular damage on membranes and organelles, including chloroplasts. Thus, energy is wasted and photosynthetic efficiency reduced (see *Environmental Pollution and Function of Plant Leaves*). These harmful effects on the flora may cause a chain reaction with serious consequences to the survival of the fauna, including humans.

To survive, plants need to circumvent, tolerate or defend against various *biological environmental factors*, including herbivores, insects, pathogens, and competition with other plants. Usually, plants and other organisms have evolved a balanced co-existence, or 'biological equilibrium', at the natural habits. Disturbance of the system may cause devastating effects on plant populations. For example, air pollutants may change the living conditions of insects and/or affect the defence mechanisms of plants, which may cause an insect outbreak and increased damage on plants (see *Plant-Insect Interactions and Pollution*). In man-made environments, such as arable fields in agriculture, the balancing systems are disturbed or non-functional, and the plants are vulnerable to outbreaks of insect pests and disease epidemics. There is competition for space, light, water and nutrients amongst individuals and between species of plants. Success in competition for the suitable growth environment is crucial for the establishment and survival of individuals and species within a plant community. Adaptation to the prevailing growth conditions determined by the physical and biological factors discussed above is a fundamental requirement. However, plants have developed additional mechanisms to suppress the growth of their competitors using certain compounds and metabolites. The chemical interactions by which plants regulate seed germination and growth of each other are an important factor affecting the structures of plant communities (see *Biochemical Interactions among Plants: Allelopathy as Ecosystem Regulator*). The climatic change and biological factors, such as insect pests and pathogens of plants, may affect the plant-plant interactions. The microbial communities in soil and the root environment (rhizosphere) seem particularly important but have been little studied.

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Bibliography

For details, the reader is referred to the homepage of the Sanger Institute, UK (http://www.sanger.ac.uk/).

Biographical Sketch

Jari P.T. Valkonen was born in 1964.

Education: Doctor of Agriculture and Forestry (plant pathology), University of Helsinki, 1993.

Working career:

Visiting Scientist, Department of Biochemistry and Plant Physiology, AFRC Institute for Arable Crop Research, UK, 1989-1990.

Visiting Scientist, Department of Pathology, International Potato Center (CIP), Peru, 1990-1991.

Researcher, Department of Plant Production, University of Helsinki, Finland, 1991-1992.

Visiting scientist, Department of Plant Pathology, Cornell University, USA, 1993-1994.

Research Fellow, The Academy of Finland, 1993-1997.

Group Leader, Institute of Biotechnology, University of Helsinki, 1996-2001.

Professor of virology, Swedish University of Agricultural Science (SLU), Uppsala, Sweden, 1997 –2006

Professor of plant pathology, University of Helsinki, Finland, 2001-

Academy professor, Academy of Finland, 2006-

Other tasks:

Dean, Graduate School on Plant-Microbe Interactions (IMOP), SLU, Uppsala, Sweden, 2003-2006 (membership of two other graduate schools).

Coordinator of the ScanBalt/NorFA/NOVA network on “Agrobiotechnology research on root-microbe systems (AB-RMS)”.

Senior Editor in Molecular Plant Pathology and Annals of Applied Biology

Chairman, The Scientific Agricultural Society of Finland., 2004-2007

Member, The Finnish Academy of Sciences.